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Cover: Crater Lake

[*Courtesy Devereux Butcher and National Parks Magazine, see page 293*]

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Science and Technology

(From the month's news releases; publication here does not constitute endorsement.)

Primary Monohydric Alcohol

Abitol, a primary monohydric alcohol, is described in a new technical booklet that includes a discussion of the use of the product in alkyd resins, as well as a discussion of its properties and its general applications to adhesives, fixatives, hot-melt coatings, oil additives, wax additives, and surfactants. (Hercules Powder Co., Dept. SM, Wilmington 99, Del.)

Nucleonics Catalog

A catalog describing various instruments, equipment, and chemicals for use in nucleonics has been published by Tracerlab. Sections of the 112-page manual are devoted to such items as scalers and accessories, survey meters, Geiger-Müller tubes and accessories, scintillation and safety equipment, and custom, industrial, and medical equipment and service. Catalog D. (Tracerlab, Inc., Dept. SM, 130 High Street, Boston 10, Mass.)

Crucible

Ultrahigh-temperature crucible made of Borolite (zirconium boride 101) has a melting point of 3900°F. Designed for use in work with molten metals, such as aluminum, brass, copper, iron, magnesium, and lead, the crucible is corrosive-resistant to nitric and hydrochloric acids. (Fisher Scientific Co., Dept. SM, 717 Forbes St., Pittsburgh 19, Pa.)

Electrometer

Vibrating-reed electrometer model 31 is suitable for mass spectrometry, measuring radioactivity and electric properties, determination of isotopes such as carbon-14, tritium, sulfur-35, and for other applications. The new instrument is capable of detecting currents as small as 1×10^{-5} μμa originating in a high-impedance source. Voltages as small as 0.02 mv can also be detected. (Applied Physics Corp., Dept. SM, 362 W. Colorado St., Pasadena, Calif.)

Atomic Energy Materials

Booklet entitled "Atomic energy materials" covers the uses and properties of such basic elements as cadium, cobalt, titanium, uranium, and zirconium. Copies are available. (National Lead Co., Dept. SM, 111 Broadway, New York 6)

Radiation Absorbers

A 20-page booklet published by Antara Chemicals discusses the absorption characteristics, compatability in plastics, solubilities, and other properties of four substituted benzophenones. These light-yellow powders are used to control harmful effects of ultraviolet radiations. (Antara Chemicals, Dept. SM, 435 Hudson St., New York 14)

Vacuum Evaporation

Steel pump plate designed for vacuum evaporations is useful for experimental evaporation and sputtering of metals, multilayer coatings, vacuum melting of metals, and vacuum impregnation. The plate measures 17 in. in diameter by ¾ in. in thickness and is ground to precision tolerances on the upper surface. Eight holes are provided for feed throughs and accessories. (Central Scientific Co., Dept. SM, 1700 Irving Park Road, Chicago, Ill.)

Mercury Sweeper

A new "sweeper" is designed to retrieve spilled mercury from uneven surfaces. Retraction of the amalgamated copper wire roller draws the liquid into a pan from which it can be poured. (Eberbach and Son Co., Dept. SM, 200 E. Liberty St., Ann Arbor, Mich.)

Plastic Petri Dishes

Throw-away petri dishes for use in the microbiological laboratory are sterile and pyrogen-free. They are made of optically clear styrene plastic with a heat-distortion point of 90°C, a material that is inert to biological reagents. (Chicago Apparatus Co., Dept. SM, 1735 N. Ashland Ave., Chicago 22, Ill.)

Infrared Spectrophotometer

The Beckman infrared spectrophotometer, model IR-4, incorporates a double monochromator for spectral purity and high resolution. It may be operated on a double-beam system for quick scans and convenient data presentation or on a single-beam system for greater quantitative accuracy in chemical analyses. (Beckman Instruments, Inc., Dept. SM, Fullerton, Calif.)

X-ray Diffraction Instrument

A high-speed proportional counter and preamplifier incorporated in the new General Electric x-ray diffraction instrument frees x-ray diffraction techniques from dependence on conventional Geiger counters and permits accurate, rapid analyses. A single-crystal orienting device permits analytic chemists and physics researchers to analyze fibers and wires and to study preferred orientations by the reflection method. Direct count of line area, even for intense, wide lines, can be made at rates exceeding 100,000 counts/sec, with a count capacity of 100 million. The preamplifier enables the detector to perform linearly in a range about 5 times greater than is possible with multichamber Geiger counter asemblies. A helium atmosphere is substituted for air in quantitative determinations of widely known elements of small atomic number. (General Electric Co., Dept. SM, 4855 Electric Ave., Milwaukee 1, Wis.)

Reference Manual

Instrument reference manual designed to familiarize laboratory workers with instrument methods of analysis is available from Coleman. This publication contains a complete description of the most commonly used methods of instrument analysis, including spectrochemistry, nephelometry, colorimetry, *p*H measurement, fluorimetry, and flame photometry. (Coleman Instrument Co., Dept. SM, Maywood, Ill.)

Infrared Analyzer

Infrared CO_2 analyzer, Liston-Becker model 16, is described in a new folder. Equipment is illustrated in various operational setups and described with emphasis on its speed, specificity, and accuracy. Characteristic recording traces are included showing normal respiration, hyperventilation, breath holding, and calibration operations. The publication includes specifications and an extensive bibliography covering applications of infrared CO_2 analyzers as well as effects of abnormal CO_2 levels. (Spinco Div., Beckman Instruments, Inc., Dept. SM, 732 O'Neill Ave., Belmont, Calif.)

Coulomatic Titrimeter

A new coulomatic titrimeter is designed to eliminate standard solutions from the chemist's list of problems. It generates ions of titrant electrically, right in the sample. There are no solutions to standardize and restandardize, and the titration is carried out automatically from start to finish. The instrument is equipped with a wide variety of interchangeable, "unitized" electrodes, so that it can perform a number of difficult analyses for which there are no other satisfactory rapid methods. Its biggest uses are for speeding and simplifying determinations of mercaptans in petroleum products and halides in trace quantities. Less than 30 μg of mercapatan sulfur (0.0006 percent in a 5-ml sample of gasoline) can be determined with $\pm$1-percent accuracy, according to Fisher engineers. (Fisher Scientific Co., Dept. SM, 717 Forbes St., Pittsburgh 19, Pa.)

Electron Microscope

Field emission electron microscope capable of magnifications up to 2 million diameters is available either as a classroom demonstration model or as a completely equipped research instrument for applications in metallurgy, lighting, communications, crystallography, catalysis, and oxidation-reduction processes on metallic surfaces. The instrument consists of a fine needle sealed into one end of an evacuated tube that points toward a fluorescent screen at the opposite end. When 5000 v are applied to the needle field, emission is strong enough so that the resulting picture can be projected on a large screen or photographed with a motion-picture camera. The instrument and accessories are approximately the size of a typewriter; controls are designed for operation by inexperienced personnel. (National Instrument Laboratories, Dept. SM, 6108 Rhode Island Ave., Riverdale, Md.)

Organic Chemicals

Recently added to the Eastman list are the following: maleo-pimaric acid; *m*-bromo-α,α,α-trifluorotoluene; 5-chloro-2-hydroxy-4-methylhexanophenone; di-*n*-hexyl carbonate; 1-ethyl-1-(1-naphthyl)-2-thiourea; α-hydroxy-isobutyric acid; indoline; methyl 2-bromo-*n*-butyrate; 5,6,11,12-tetraphenylnaphthacene; and 2,4,7-trinitro-9-fluorenone. (Distillation Products Industries, Dept. SM, Rochester 3, N.Y.)

Washing Machinery

"Precision washing machinery" is the title of a new booklet that describes two main types of automatic and semiautomatic friction-method cleaning machines, pressure-spray jet washers, and powered out-of-water brush machines. (Southern Cross Mfg. Corp., Dept. SM, Chambersburg, Pa.)

Distillation Unit

Vacuum distillation unit gives closely identical results over a wide range of conditions and improves results obtained from ASTM-type vacuum distillations. Made of Pyrex glass, it incorporates all the equipment necessary to perform ASTM method D-1160-52T. The unit was developed by H. S. Meyers and A. T. Kiguchi of C. F. Braun and Co. (Glass Engineering Laboratories, Dept. SM, 602 O'Neill Ave., Belmont, Calif.)

Hood

Dust-proof hood for performing operations under stereomicroscopes eliminates dust by forcing outside air through a blower system and into a plenum chamber. This blower system is capable of filtration to ½-μ efficiency and provides for external removal of filters. (P. M. Lennard Co., Dept. SM, 196 DeGraw St., Brooklyn 31, N.Y.)

Oscilloscope

Designed specifically for biological use, a new oscilloscope can be used to monitor physiological processes. Called the Viso-scope, it is exceptionally simple to operate and utilizes a minimum of controls. The unit can be used to view several phenomena simultaneously or alternately by means of a selector switch. Provision for attachment to a recording system has been included. (Sanborn Instrument Co., Dept. SM, 37 Sanborn St., Cambridge 39, Mass.)

Bacteriologist's Field Kit

Field cultivation kit for rapid bacteriological analysis of water samples utilizes a membrane filter for removing bacteria from the sample. Provision is made for incubation with a new portable incubator that plugs into the cigarette lighter receptacle of an automobile. The unit will also operate on 110 or 220 v. By means of differential media, colonies of bacteria can be readily observed and identified within a 24-hr period. (Millipore Filter Co., Dept. SM, Watertown 72, Mass.)

Molybdenum Data Sources

Technical data on analysis, preparation, properties, and applications of molybdenum chemicals is available in 68 papers published by Climax Molybdenum. A recently compiled catalog of these bulletins lists several on cyanomolybdates, halides and oxyhalides of molybdenum, organic complexes of molybdenum, heteropolymolybdates, and molybdenum disulfide that are included in a new series prepared for Climax by the Battelle Memorial Institute. (Climax Molybdenum Co., Dept. SM, 500 5th Ave., New York 36)

Freeze Dryer

Designed to simplify routine preparation of tissues for sectioning and for microchemical and optical studies, a new histological freeze dryer can run up to eight sections at one time. It is equipped with an individual chamber for evacuating the imbedding medium. Several units may be operated simultaneously from one vacuum pump. Drying time for most tissues is less than 6 hr at temperatures of −40°C bath and −78°C condenser. (E. Machlett and Son, Dept. SM, 220 E. 23 St., New York 10)

Ethanolamines

Three ethanolamines are discussed in a 48-page booklet recently published by the Nitrogen Division of Allied Chemical and Dye. Included are physical property graphs and information on applications and specifications of these substances, as well as data on their physical, chemical, and physiological properties. (Allied Chemical and Dye Corp., Dept. SM, 40 Rector St., New York 6)

Source and Microwave Exciter

Used in high-dispersion interferometry, Baird's new source and microwave exciter makes wavelength determinations with accuracies to 1 part per million. It utilizes a fused quartz electrodeless lamp containing about 0.4 mg of Hg^{198} prepared by transmutation of gold. The portable exciter unit operates at a 12.2-cm wavelength and is powered by a 60-cy/sec, 115 v alternating-current supply. (Baird Associates, Inc., Dept. SM, 33 University Rd., Cambridge 38, Mass.)

Microscope

The Johansson microscope measures thicknesses down to 0.1 A. It was designed at the Institute for Optical Research in Stockholm, Sweden and will soon be demonstrated in this country. (Junger Co., Dept. SM, Stockholm, Sweden)

Electrograph

An electrograph that provides instantaneous oscillograms has been developed. Utilizing electrosensitive paper, with automatic sensitizing and dry developing and fixing, the instrument is capable of 24-trace recording by light beam to 100 cy/sec without amplification. (Century Electronics and Instruments, Inc., Dept. SM, 1333 N. Utica St., Tulsa, Okla.)

Incubator

Temperatures from 5° to 50°C may be maintained in a new Central incubator cabinet. A dial thermometer on the door registers inside temperature. The unit will accommodate 120 bottles of 190-ml size or 105 bottles of 300-ml size. (Central Scientific Co., Dept. SM, 1700 Irving Park Rd., Chicago, Ill.)

Rectilinear Recording Milliammeter

A milliammeter that records signals in their rectilinear appearance is now available. Rectilinear writing is made possible by a pantographic linkage, which includes a gimbal mounting for the pen and a freely moving frame with counterbalancing weights that insure uniform pen pressure throughout the deflection. (Texas Instruments Inc., Dept. SM, 6000 Lemmon Ave., Dallas 9, Tex.)

Monochromatic Condenser

Illumination for ultraviolet microscopy and photomicroscopy is provided by a new monochromatic condenser. Attached to a 500-mm monochromator, the lens system permits the ultraviolet light source to be moved 10.25 in. from the photomicrographic equipment. The condenser illuminates the complete field of view of the microscopic image. (Bausch and Lomb Optical Co., Dept. SM, 635 St. Paul St., Rochester, N.Y.)

Water Conditioner

A new device for preventing scale-formation in boiler and air-conditioning systems and other heat-transfer systems subjects flowing water to alternating magnetic fields. The unit consists of two sections, dispersing cell and homogenizing chamber, and contains no moving parts. Crystallization is retarded, and dissolved salts and minerals become amorphous powders that remain in suspension or settle out as drainable mud. (Pakard Manufacturing Co., Dept. SM, 2220 W. Beaver St., Jacksonville 9, Fla.)

Electron Diffractograph

An instrument that can be used in structural studies for direct observation or photographic recording of electron diffraction patterns of surfaces and thin layers has been developed. The electron diffractograph utilizes a metal discharge tube with a cold cathode. A beam 10 μ in diameter is accelerated through a variable potential of 20 to 50 kv toward an anode diaphragm in a self-centering cone, which permits an optical line width of more than 100 μ. Specimen temperature, monitored by a thermocouple, can be increased to 1000°C. The observation chamber has three viewing ports, with a pivotable fluorescent screen. Two electromagnetic lenses of variable focal length make it possible to focus on the fluorescent screen for powder diagrams, on the sample for small-beam diffraction, and above the sample for shadow microscopy. Magnified images of the sample and of reflections can also be obtained. (Norden-Ketay Corp., Dept. SM, Snow and Union Sts., Boston, Mass.)

THE

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JUNE 1956

Current Problem in Perspective

CHARLES DOLLARD

Dr. Dollard, who has been a member of the National Science Board since 1950, is chairman of the board's committee on Scientific Personnel and Education. From 1938 to 1954 he was a member of the staff of the Carnegie Corporation of New York, of which he was president from 1948. Prior to that, he served on the administrative staff of the University of Wisconsin, where he received his training. During World War II he served first as chief of the research branch, Information and Education Division, U.S. Army, and later as deputy director of the division.

THE problem that I am to discuss can be stated with relative simplicity. The United States has achieved an unexampled level of material prosperity, chiefly by exploiting its own scientific discoveries and those of other nations. There is a chicken in every pot and an electric stove to cook it on, a car in almost every garage, and a television aerial on every other roof. Science enables us to live longer, work less, dress more comfortably in all kinds of weather. We no longer have to leave the house to go to the movies. We can lunch in New York and dine in San Francisco on the same day, or spend the weekend in Paris without missing more than a day at the office. We are eating high off the hog, thanks to science and its handmaiden, technology.

We have not, indeed, achieved this prosperity without exciting envy and aggression in other, less prosperous nations. There is a considerable portion of the world's population that regards us with unfriendly eyes and that would be glad to see us one with Nineveh and Tyre. Here again our main dependence is on science. The enemy may outnumber us 10 to 1, but so long as we are confident that we have the edge on him in science and technology, we feel relatively secure. The very heart of our defense system is the relatively small corps of scientists who man our laboratories.

Here we are then in the midst of the 20th century, fat and prosperous, and for the moment, at least, relatively secure against aggression from abroad. The fly in the ointment is that we have become painfully aware that the army of science is not getting enough recruits. There is disagreement about the extent of the shortage in the ranks, but there seems to be no disagreement about the central fact. The annual demand for men trained in science and in engineering exceeds the annual output of our colleges and universities by a considerable margin. And the steady decline in enrollment in science courses in our high schools and colleges gives rise to the fear that the situation is getting worse rather than better To add to our worries, word comes from the enemy's camp that his potential in science and technology, measured in terms of trained manpower, is growing apace and will soon exceed ours if indeed it does not already do so.

The relative decline in high-school enrollments in science and the undersupply of college graduates with good training in science and engineering are phenomena that can be measured. More frightening but less measurable is the possibility that science

in this country is no longer attracting to its ranks a fair share of the relatively small fraction of our population that is capable of first-rate intellectual work. The lack of well-trained technicians to man our expanding laboratories and drafting rooms is cause for alarm. The failure to recruit the much smaller number of men in each generation who are capable of the original and creative work that makes science a growing thing might easily be fatal. We cannot hope to maintain our industrial preeminence or our defenses against outside aggression merely by exploiting yesterday's scientific discoveries.

Criticisms and Replies

When any group or nation is confronted with a problem that threatens its welfare, its first reaction is to look for a scapegoat. If something is wrong, someone is to blame. In this case, the search for the villain in the piece has been going on for several years. Recriminations are the order of the day. The scientists blame the public schools for drying up the pool of talent on which science depends by diluting the curriculum, by substituting the pablum of courses in social adjustment and citizenship for the good red meat of chemistry, Latin, and mathematics. Some of the more extreme critics of the public schools go so far as to allege a plot by which the teachers colleges of the country have degraded the high-school curriculum to conceal the incompetence of their own graduates. High-school programs nowadays, these extremists say, are determined by what the teacher is capable of teaching rather than by what the student should learn.

As might be expected, the teachers are ready with answers to their critics. Indeed, they have some indictments of their own to offer. They point out that, whereas in 1900 they had to serve only the top 10 percent of the population of high-school age, they now must accommodate 80 percent; and that this vast increment represents in large measure the children and grandchildren of foreign-born Americans. The public-school teachers remind us also that their share in our phenomenal prosperity has been a meager one and that they are, on the average, paid less well than railroad switch tenders or brick layers. In defense of their much abused curricular innovations, they protest that, especially in the cities, the public schools are now called upon to perform many of the youth-training functions once performed by the family and the church and that they have become the major instruments for preparing children with diverse family and ethnic backgrounds for life in a society much more complex and confusing and competitive than that which their fathers knew. They argue that if they are to be blamed for juvenile delinquency and gang warfare, they must be allowed to spend a fair share of the school day dealing with problems that give rise to these difficulties. If the curriculum has changed, they say, it is only in response to changes in the size and the diversity of the population that the school must serve.

The liberal arts colleges have also come in for their share of blame. Like the high schools, they are accused of offering a vast assortment of trivial courses that cater to the weak and tempt the strong to take the easy, rather than the hard, route to the baccalaureate degree. They are charged with loading the dice against programs of study that require real intellectual effort by offering alternative programs that, for the bright student, involve almost no effort at all.

The critics of the colleges also charge that these institutions share the blame for the decline in high-school standards by reason of their failure to motivate their best students to become teachers. To this the colleges reply that so long as their graduates can earn twice or three times as much in business or industry as they can earn in teaching, the situation is not likely to change markedly. Finally, the colleges complain with increasing bitterness that government and industry are making a bad situation worse by bidding away from the colleges the able young scientists who are so badly needed to train the next generation. How can we be expected to produce better crops, ask the colleges, if our seed corn is taken from us?

The Federal Government comes in for its share of blame too. It is accused of diverting our best teachers to defense research, either by awarding fat contracts to the universities or by offering individual teachers large inducements to move to government laboratories. And on all sides we hear the complaint that the government is using the power of the purse to divert effort from the basic research that keeps science on the march to developmental work that merely exploits last years' discoveries.

Each of these indictments has a large element of truth in it. By denying teachers as a group a fair share in our national prosperity, we *have* suffered a loss in the quality of teaching all along the line and especially at the secondary-school level. Industry and government *have* made it hard for the colleges to hold able men in their faculties by offering salaries that the colleges couldn't possibly afford to match. We *have,* indeed, been eating our seed corn. The teachers colleges *have* gone overboard

CRISIS IN SCIENCE EDUCATION

These three articles—"Current problem in perspective," by Charles Dollard; "Nation's interest in scientists and engineers," by Arthur S. Flemming; and "Role of the Federal Government in science education," by Alan T. Waterman—are based on papers presented at a symposium, The Crisis in Science Education, *that was held in Atlanta, Ga., on 29 Dec. 1955 during the annual meeting of the AAAS.*

on method as against content. Many of our teachers, especially in the sciences, *are* badly trained. The high-school curriculum *is* less rigorous than it once was, and many of our colleges *are* offering a host of courses that have little intellectual content. We *have* undoubtedly burdened our public school system with a great many tasks that have little or nothing to do with training the mind.

Steps toward Improvement

Now it would be quite misleading to imply that in this crisis all our energies have been devoted to a futile search for a whipping boy. On all sides we see encouraging and intelligent efforts to do something about the situation. The American Association for the Advancement of Science is now conducting a major study of ways and means to improve the teaching of science at all levels. The Ford Foundation has raised the flagging spirits of college teachers everywhere by its magnificent series of gifts for the improvement of faculty salaries. To an ever-increasing degree, industry is recognizing its responsibility by making unrestricted grants to colleges and universities and by supporting scholarship programs designed to reduce the loss of talent which we now suffer by reason of the failure of many of our brightest students to enter college. The Fund for the Advancement of Education is supporting a variety of studies and experiments looking toward the improvement of teacher training, better utilization of our present supply of teachers, and the development of more challenging programs for the very bright high-school students. The Federal Government is moving on various fronts too.

The aggregate effect of all these measures is bound to be good, and we are justified in looking for some improvement all along the line. The changes will not be dramatic or sudden. In attempting to reverse the trend, we must pay the price of having a highly decentralized educational system in which change must be accomplished by example and persuasion rather than by fiat.

To me, one of the most heartening aspects of the situation is that most of the remedial efforts on the educational front to which I have referred recognize the fact that first-rate scientists are not wholly the product of good training in science. To the best of my knowledge, no one has seriously proposed that we should attempt to solve our present dilemma at the expense of neglecting other aspects of the great tradition of liberal education, of which science is a part. There seems to be a general awareness that the student who has not been permitted and encouraged to cultivate a taste for the arts, for literature, for philosophy, and for the social sciences is unlikely to develop the breadth of mind and the habits of thought that distinguish the real scientist from the technician and the gadgeteer. There seems to be general agreement that science will be best served not by improvement in science teaching alone but by raising standards of instruction across the board.

In the course of preparing this paper I was reminded of a speech that the late Frederick Lewis Allen, long-time editor of *Harper's Magazine,* delivered in New York some years ago. Allen recalled that as an undergraduate he had been impressed by the determination of his roommate, Louis Zahner, to make his name ring down the corridors of time by stating a law that should bear his name. In his last term at Harvard, Zahner achieved his objective. Zahner's law, as Allen pointed out, is in the great tradition. It admits of no exceptions. It can be tested empirically. It requires only ten words for its statement. It runs as follows: "If you play with anything long enough, it will break."

Allen confessed that he was so jealous of his friend's achievement that he could not rest until he had matched it. Allen's law covers a wider range of phenomena than Zahner's, but it too is characterized by elegance and simplicity. It reads as follows: "Everything is more complicated than it seems to most people." Does Allen's law apply to the present situation?

Will Young People Choose Science?

Assume for the moment that our various efforts to toughen the curriculum and improve teaching

achieve a fair degree of success. Assume that at least the best of our high schools can be motivated and enabled to teach chemistry and physics and biology and mathematics as well as these subjects are now taught in the freshman year in the best of our colleges. Assume, finally, that our young people today are on the average as idealistic and no lazier than American boys and girls ever were. Does it follow that an adequate number of our most gifted young people will seek careers in science? Are there other factors to be defined and dealt with, more subtle than those already discussed, which are making science as a career less attractive to young people than it once was?

This question arises because, as one surveys the educational scene, one is impressed by the fact that our schools and colleges, with all their weaknesses and imperfections, are still managing to produce an adequate—or more than adequate—number of candidates for admission to other professional fields in which standards of training and performance are relatively rigorous. Our medical schools have at least 3 times as many qualified candidates as they can handle. Our law schools are overflowing. Graduate departments of psychology and economics are besieged with candidates for advanced training. Are students entering these disciplines rather than the basic sciences, not because they are lazy or because science is poorly taught, but because science no longer presents itself to the young as a field of human endeavor in which a man can achieve a full and free and useful life?

Before attempting an answer to this question, it might be well to consider for a moment the context in which young people in our society determine their life careers. As in other aspects of our culture, the doctrine of *laissez faire* holds. There are many influences but no directives, many suggestions but no commands. Parental ambitions play a part. So does admiration for gifted teachers, or for lawyers, doctors, clergymen, and other adults within the circle of the child's experience. Ours being a culture in which money is a very important value, the question of material rewards weighs heavily with the majority. The best evidence we have indicates that career choices tend to be made at about the ninth grade.

One factor that undoubtedly plays a part in leading young people, especially the more idealistic ones, in one direction or another is the public image of each profession or calling that is current at the time the choice of career is made. This public image, or stereotype, is a product of various forces and may have little basis in fact. Indeed, fiction plays a major part in its formation. I suspect, for example, that many young men born in Great Britain in the second half of the 19th century were diverted from careers at the bar by reading Charles Dickens' novels, which, as you will recall, pictured all lawyers as unprincipled, self-seeking charlatans with no concept of public service. Molnar served the doctors of his time in much the same fashion. Conversely, Kipling's romantic picture of the life of the British soldier in India undoubtedly helped to keep the Queen's armies abroad well supplied with recruits. In our own time, such novels as Maugham's *Of Human Bondage* and Thompson's *Not as a Stranger* have done much to make medicine appear to the young as a career at once exciting and socially useful.

The tide of events, national and international, plays its part too in the formation and alteration of these public images. Bankers lost caste during the dark days of the depression; at the same time the freshness and excitement of the New Deal attracted hundreds of able and idealistic young men to government service.

Has something happened in recent years to the public image of science and the scientists—some change that makes science less appealing to the most gifted and idealistic young people of our time than it was to earlier generations? To answer this question satisfactorily would take a great deal of research. We should have to know much more than we now do about factors that affect the career choices of young people. But even in the absence of such exact knowledge, I offer some speculations.

To the boys of my generation, science wore two faces. One was the face of a fictional character named Tom Swift. Tom Swift was a boy genius, who single-handedly produced a flow of marvelous devices and gadgets more spectacular than the combined output of Alexander Graham Bell, Thomas Edison, and the Wright brothers. Tom Swift made the life of the inventor appear to be at once the most exciting and the most profitable that a boy could possibly choose. I suspect that he drew a substantial number of my contemporaries to careers in engineering and science.

The other face was a composite of Ben Franklin, and Darwin, and Newton, and all the other great men of science whom we encountered in our history books and in our outside reading. This composite picture appealed to a much smaller number of my contemporaries. It suggested long years of hard work, and self-discipline, and short rations. But for the idealistic it opened up vistas of a life of great personal satisfaction and benefit to mankind, with the possibility of fame at the end of the road.

Now, different as they were, these two images had something in common. Both suggested unlimited opportunity to indulge one's curiosity, to

follow one's own nose, to work alone if one chose and at one's own pace. Although one route led to fortune and one, at best, to fame, both involved a journey full of excitement and both symbolized freedom in all its aspects.

Does my son's generation have the same image, or images, of science and technology? I wonder. I suspect that to our young people today the scientist appears as a man who works under wraps, on small segments of highly specialized problems defined by someone else—a man under pressure to get an assigned job done, hardly less subject to authority than an Army recruit. I suspect that the image of science as a life of freedom and high adventure may have been one of the major casualties of the last war.

At this point I must remind you that I am speaking of images rather than of realities, of how science looks from the outside rather than from the inside. I'm sure that the image of the scientist that I have recalled from my own high-school days is a most romantic and unrealistic one. I am equally sure that, in spite of security regulations and all the other heavy burdens that considerations of national defense impose on scientists, in spite of all the pressures toward programmatic research, in spite of vast, highly organized laboratories, science is still for the most part the land of the free. I'm sure, too, that the role of what James Conant aptly called the "uncommitted investigator" is no less important and challenging than it was in Newton's day. Nevertheless, I am convinced that the public image of the scientist is quite a different one.

Possible Means to an Answer

If misconceptions regarding the conditions under which scientists live and work are to a greater or less extent keeping young people out of science, what can we do to remedy the situation? I don't think there is any simple answer to this question. If there is, I'm not ready with it.

Undoubtedly some of the steps that have already been proposed will help. We know, for example, from such studies as that of Goodrich and Knapp that the gifted science teacher can make science appear to be the most interesting and rewarding of all professions. But there never has been and never will be enough such teachers to go around. It therefore behooves us to think of other means of giving young people a truer image of science.

In discussing this problem with teachers and others interested in science education, I have come upon one suggested experiment which I think might be worth conducting. The essential steps in this experiment are as follows. (i) Choose two communities of approximately 100,000, which so far as can be judged have high schools of about the same quality. (ii) Within these two communities identify all the ninth graders who appear to have the capacity to do well in college, whether in science or in any other field. (iii) Expose the selected children in one community to every possible experience that would help to give them a fair picture of what scientists do, how they work, and what their rewards are, leaving the children in the other community, so to speak, in the dark. When I say every possible means, I intend to include not merely printed materials or lectures but also visits to laboratories, opportunities to ask questions of working scientists, perhaps even actual employment in a laboratory for a brief time. The essential aim would be to enable youngsters to smell and feel science as well as read about it and hear it discussed. (iv) Without changing the course of study usually available to either group, or the teachers, determine how many students from each group choose science as a major when they enter college.

If the exposed group, to borrow a medical term, produced a significantly larger number of recruits for science than the unexposed, we would have at least a clue as to what part misconceptions about science as a career play in depleting its ranks.

I referred earlier to the fact that our concern over declining enrollments in science was increased by news from abroad. If the figures that we are now getting on the present and prospective production of scientists and engineers in the Soviet Union are reliable, we may fairly assume that the Communists are resorting either to bribery or to conscription. Since the Communist government now controls all the educational facilities within its borders, the problem of who shall study what is a simple one for them to solve.

Our value system commits us to a much more difficult program. We can undoubtedly increase the enrollment of our engineering schools measurably by increasing the salaries of engineers, and we undoubtedly will. But science as a creative activity must compete for talent against all the other exciting and socially useful professions and vocations which a great industrial nation offers to its young men and women. It will be given an advantage in this competition by all the steps now under discussion—by better teaching, better teaching facilities, better textbooks, better means of identification of the most gifted children and more attention to their needs. But in the last analysis, science cannot hold its own in this country unless we convince our young people that, as of old, the life of the scientist is a life of freedom, of adventure, and of self-fulfillment.

Nation's Interest in Scientists and Engineers

ARTHUR S. FLEMMING

Dr. Flemming has been director of the Office of Defense Mobilization on leave as president of Ohio Wesleyan University since 1953. He received his training at Ohio Wesleyan, American, and George Washington universities. Between 1927 and 1939 he taught at American University, worked on the editorial staff of the U. S. Daily *(now the* United States News and World Report*), and was director and executive officer of the School of Public Affairs. Since 1939 he has held various Government posts on the Civil Service Commission, the War Manpower Commission, the Commission on the Organization of the Executive Branch of the Government, the President's Advisory Committee on Government Organization, and others. He became president of Ohio Wesleyan University in 1948.*

ALL of us, I feel sure, would agree that sufficient evidence has been accumulated to support the following conclusions. (i) We are not utilizing in the most effective possible manner those who have been trained as scientists and engineers. (ii) Our educational system is not providing us with the number of well-trained scientists and engineers that we need today and will need in increasing numbers in the days that lie ahead.

As a result, in the United States and throughout the free world, the concern is being expressed that we may not make the progress in the field of technology that is demanded by the requirements of national security. If we fail to overcome these deficiencies, our ability to deal with the forces of international communism from a position of strength would be seriously undermined. Therefore, the problem we are considering is a matter of grave concern from the standpoint of national security. A positive program carried forward with a great sense of urgency is needed if we are to deal with this situation effectively.

Management Competence

We must raise the level of management competence in the fields of business, government, and education. We are confronted with a serious situation because those who have been given management responsibilities in these fields have failed to measure up to the opportunities that have confronted them. In all three areas there has been a failure to identify an emerging problem; a failure to utilize in the most effective possible manner the resources—both human and material—that have been available; and a failure to provide a climate that challenges men and women to live up to their highest possibilities.

A Science Advisory Committee under the chairmanship of Lee DuBridge, president of California Institute of Technology, advises both the President and the director of the Office of Defense Mobilization. Recently a subcommittee of this committee made a report on the effectiveness of certain scientific laboratories.

In commenting on one government laboratory, the committee said:

"If one recalls the real doubts that the laboratory could even survive, then its strength, vigor and superb accomplishments of the past several years must be acknowledged as outstanding phenomena.

"What then brought the laboratory back to life, to health, and to high achievement? Two things—closely related:

"1. Leadership at the laboratory and in the organization above the laboratory.

"2. A job to do—important and comprehensible."

And then, in commenting on the effectiveness of one of the nation's outstanding industrial laboratories, the committee said, "It is productive and has strong leadership—by any standards."

In other words, if we are to solve the manpower problem that exists in the fields of science and engineering, we first must do a far better job than has been done up to now of providing effective leadership in the field of human relations. Both scientists and nonscientists have been and will continue to be called on to provide such leadership.

Business is placing a constantly increasing emphasis on executive development programs. The

fields of government and education have not given anything approaching equal recognition to the importance of such programs. All three areas can and must do a great deal more than has been done in the direction of raising the level of competence on the part of those who are now exercising leadership in these areas.

We cannot wait for tomorrow's leaders. We must improve the quality of today's leadership in the field of management.

Looking ahead to the future, however, we are likely to find ourselves up against an even more serious situation. In our educational institutions there is a trend in the direction of a high degree of specialization. In this increasingly complex world, the trend is almost sure to continue. It must, however, be accompanied by adequate emphasis on work in the humanities, social studies, philosophy, and religion. Such studies are absolutely essential if management personnel of tomorrow are to be provided with a center and direction for their lives. Without such a center and direction, it will be impossible for them to provide the leadership that we must have if we are to solve our manpower problems in all areas.

Efficient Use of Technical Personnel

Specific and effective efforts must be made by business, government, and education to utilize more effectively those who have been trained as scientists and engineers. It is conceivable that the years that lie immediately ahead may constitute our most important years in terms of maintaining technological superiority for the free world. One group that has been studying this problem puts it thus: "Unless the short-run problem in the decisive period which we are approaching is successfully solved, there may be no long run."

We are focusing our attention as never before on what needs to be done in our secondary schools and in our institutions of higher education in order to improve the training of future scientists and engineers. This is all to the good. If we are not careful, however, it can become a device for distracting our attention from the problem most immediately at hand. If we fail to measure up to our technological potential in the next few years, it will be because of our failure as a society to utilize effectively those already trained as scientists and engineers.

We have not, for example, provided scientists and engineers with incentives designed to keep them engaged in basic research activities. In fact, we have done just the opposite. We have been very successful in thinking up incentives that have drawn competent research scientists and engineers out of the field of basic research over into the area of applied research.

Here is a quotation from the annual report of the director of a scientific activity within an institution of higher education: "Unfortunately he [a very promising scientist in the research field] is at the moment being enticed away from the academic life by the salary of commercial research organizations. We are afraid that unless we can make him an attractive offer . . . . the profession may lose forever one more well-trained fundamental research man."

All of us know that that story can be duplicated thousands of times in all parts of our nation. And let us not condemn the commercial organizations for making the offers. Rather, let us concentrate on a positive approach that will result in solving the human and economic problems that are involved in this situation in such a manner as to provide the incentives that will keep such a man in the field of basic research. We need to do a better job of reflecting in our personnel practices our convictions about what is important to the life of our day.

In the field of education, to take another example, we often move an outstanding scientist into an administrative position solely for the purpose of providing him with additional compensation. When we do so, we are failing to utilize him in the most effective possible manner solely because we are unwilling to face and to solve the human relations problems that are involved in paying the scientist the same or even a higher salary than the administrator. And business and government must plead guilty to similar practices.

We are face to face with a manpower problem that is just as urgent as any we faced during World War II. Business, government, and education should be taking steps today that will identify situations where scientists and engineers are being utilized in positions that do not call for the exercise of their highest abilities. And when those situations are identified, those who occupy management positions should proceed, as a patriotic duty, to correct them.

Today's manpower problems in science and engineering must be solved today. Let us not gloss over our failure to solve them by focusing the spotlight exclusively on what educational institutions should be doing to solve tomorrow's manpower problems in these fields.

Cooperation

We must develop programs that will enable the scientists and engineers of the free world to work

together in an effective manner. The past decade has been characterized by tremendous progress in the direction of effective collaboration on the part of the nations of the free world in both the military and economic areas. We have learned that pooling our thinking and our resources strengthens all who participate in such programs.

In the scientific area, the nations of the free world have not made as marked progress in working together as we have in these other two areas. Recently, however, there has been a noticeable trend in the direction of collaboration. This trend should and must be accelerated. If it is not, we will be deliberately refusing to do all that can be done to maintain the technological superiority of the free world.

Improved Training

Our educational system must provide us with more and better trained scientists and engineers. This means that our secondary school system must be strengthened. Our salary schedules for teachers, with some exceptions, are a disgrace. Teachers do not expect to become wealthy. They desire to serve. Society should not, however, deliberately penalize them and their families because of their willingness to serve.

Our secondary-school curriculum needs to be strengthened. This becomes clear when we realize that in 1900, 56 percent of the high-school students studied algebra. Today that percentage is 24—less than half that of 55 years ago. We are confronted with the same story in geometry and an even more serious situation in physics.

In addition, our secondary school facilities need to be improved and enlarged.

When the conscience of America is aroused, however, to the place where teachers are paid a decent salary, we will attract and retain in our secondary-school system teachers who will strengthen and improve the curriculum. Furthermore, we will provide these same teachers with adequate facilities.

In other words, we are up against a serious problem in the area of secondary education because of a failure on the part of society to solve a fundamental problem in the field of human relations. If we will lift our sights, pay teachers adequate salaries, and provide them with attractive working conditions, we will be making substantial progress in the right direction.

And what is true of secondary education is true of higher education. The Ford Foundation and many corporations recognize that our failure to pay reasonable salaries is seriously undermining our system of higher education. And this nation should be eternally grateful to them for their willingness to do something about the problem by making substantial contributions to our colleges and universities.

In the field of higher education, our most difficult problems and our greatest opportunities lie ahead. I have no sympathy with those who would attempt to solve tomorrow's enrollment problems by reducing the percentage of high-school graduates attending college. The percentage must increase. We know that many exceptionally well-qualified young men and women are not receiving college education. This is one of the reasons why we are up against serious problems in the fields of science and engineering as well as in other fields.

The only way in which America can meet the challenge of communism is by widening—not narrowing—opportunities for growth and development on the part of the individual.

Recognition for Achievement

As a nation we must develop programs that will give national recognition to those who excel in the scientific and engineering fields and to those who help to make it possible for scientists and engineers to excel in their chosen fields of work. President Eisenhower in his State of the Union Message on 6 January 1955 recommended "that awards of merit be established whereby we can honor our fellow citizens who make great contributions to the advancement of our civilization and of this country."

In response to this recommendation, bills have been introduced in the Congress providing for the establishment of a "medal for distinguished civilian achievement" and for the establishment of a distinguished civilian achievement board to administer the program.

These bills should receive our enthusiastic support. If they are enacted into law they will provide an additional incentive for extraordinary effort in all areas of human endeavor.

This, however, should be just the beginning.

Consider, for example, the fields of science and engineering. Why should there not be a program that would make available at least $1 million annually for honors and awards to a large number of people who have helped to make and to keep America strong in the field of technology? Surely business and industry, working in cooperation with our great foundations, could establish such a fund on an annual basis.

Awards, for example, might be made to persons falling within the following six categories: (i) High-school students—for superior performance.

(ii) High-school teachers—for outstanding contributions in the field of teaching. (iii) College and university students—for superior performance. (iv) College and university teachers—for outstanding contributions in teaching or research. (v) Scientists and engineers—for distinguished contributions in their fields, with particular emphasis on contributions in the field of basic research. (vi) Executives in business, industry, and government—for distinguished contributions in making it possible for scientists and engineers to make the maximum possible contribution to the life of our day.

In addition, awards might be made to institutions where outstanding achievements have taken place —not because of the work of an individual but because of effective teamwork on the part of everyone connected with the institution.

This honors and awards program could range from certificates or medals to cash awards that might be comparable to the Nobel prize.

Certainly such a program should not be confined to the fields of science and engineering. However, I do believe that, because of the nation's deep-seated concern about our ability to stay out in front in the field of industrial technology, a program in these two areas could be worked out during the winter months and launched by next spring. If this were done, it would not only constitute a positive affirmation of our concern for developments in these two areas, but it would also serve as an inspiration for the establishment of similar programs in other areas.

Conclusion

If the five "musts" that I have outlined become realities, the United States and the other nations of the free world can maintain a position under which they are making full utilization of their potential in the field of technology.

If we do, we will be capable of maintaining, in the military realm, qualitative superiority in weapons and equipment. This can be one of the most effective deterrents to war.

If we do, we will be able to employ superior technology for the achievement of peaceful purposes both nationally and in cooperation with other nations. This can be one of our most effective instruments in the struggle for the hearts and minds of men.

In other words, if we do, we will be making a major contribution to the prevention of war. I do not believe that war is inevitable. I believe that it is possible for the United States and the other nations of the free world, by proceeding from a position of strength, to deter the potential aggressors.

Furthermore, I believe that it is possible for America and the other freedom-loving nations of the world to provide the spiritual leadership without which peace is but an idle dream. It requires spiritual leadership if men and women are to come to the place where they recognize an obligation to help their neighbors—nations as well as individuals—to realize their highest possibilities. It requires spiritual leadership to bring men and women to the place where they recognize that nations, as well as individuals, can save their lives only as they are willing to lose them through serving others in an intelligent and effective manner.

Out of such leadership come policies such as President Eisenhower's atoms for peace program, as well as support for policies that will bring us into a pathway that leads to peace.

And each one of us has the opportunity of helping to make sure that war is not inevitable. All of us can make some contribution in the direction of maintaining our country's position of strength. In so doing, we will be helping to deter the aggressor.

And certainly each one of us has the opportunity of helping to strengthen the spiritual foundations on which America's spiritual leadership must rest. I know of no group that can make a finer contribution in this area than those who are trained in the fields of science and engineering. Great spiritual insights come from a progressive understanding of the universe we live in. Science will more and more reveal the truth that Albert Einstein voiced in his last years—namely, "God does not play dice with the world."

We are either a part of the problem or a part of the answer to the problem. If we are failing to do everything we can to help keep America and the free world strong and to strengthen our spiritual foundations, we are a part of the problem. If we are willing to give sacrificially of our time, energy, and resources to keep America strong and to strengthen our spiritual foundations, we are a part of the answer to the problem.

We need education in the obvious more than investigation in the obscure.—Oliver Wendell Holmes.

Role of the Federal Government in Science Education

ALAN T. WATERMAN

Dr. Waterman has been director of the National Science Foundation since 1951. He received his training in physics at Princeton University, and from the close of World War I to 1948 he was a member of the faculty of Yale University. During World War II he served with the National Defense Research Committee and the Office of Scientific Research and Development. From 1947 to 1951 he was deputy chief and chief scientist of the Office of Naval Research.

WEBSTER defines *crisis* as "The point of time when it is decided whether any affair or course of action must go on, or be modified or terminate . . . a state of things in which a decisive change one way or the other is impending." I think we would agree that the mounting concern of those who are aware of the state of education in the sciences has reached the point where there is strong sentiment for effecting a decisive change. The question is therefore no longer *whether* something should be done but rather *what* should be done, and by whom.

In the United States, we have a fundamental philosophy that the education of our children is primarily the responsibility of state and local groups. In his message to the Congress on education in February 1955, President Eisenhower reaffirmed that basic tenet when he said: ". . . public schools must always reflect the character and aspirations of the people of the community. . . . Diffusion of authority among tens of thousands of school districts is a safeguard against centralized control and abuse of the educational system that must be maintained. We believe that to take away the responsibility of communities and states in educating our children is to undermine not only a basic element of our freedom but a basic right of our citizens."

In addressing myself to the question of the role of the Federal Government in relation to the crisis in science and education, I should like to analyze briefly the point at which the responsibility of state and local groups ends and at which the responsibility of the Federal Government begins. The line of demarcation is not always clear; in many situations a certain amount of overlap and merging is inevitable. Against such a background, I should then like to discuss the very considerable effort that the Federal Government is now expending on science education and to raise the question of what the form and extent of such additional effort should be.

Development of Federal Aid

Although the founding fathers were careful to establish, and succeeding generations were mindful to preserve, local jurisdiction over the school systems, the Federal Government has been conscious of its own responsibilities toward education from the beginning. An early form of Federal aid to education was the apportionment of land for this purpose. As states were added to the Union following the Louisiana Purchase, for example, the Congress granted the sixteenth section of each township from the public domain to help with the establishment and operation of the school system. In 1862 President Lincoln signed the Morrill Act, providing for the establishment of the land-grant colleges. It was only 5 years later that the Office of Education was established to serve as a focal point for Federal interests in education.

It is entirely natural that early Federal aid to education should have placed primary emphasis on agriculture. The land-grant colleges and universities are primarily schools devoted to "agriculture and mechanic arts." For the first 100 years of its existence, ours was primarily an agrarian economy. We were quick to appreciate the applications of the scientific method to agriculture, and therefore we took pains to furnish the means whereby young and struggling states could give their youth the advantages of education in the latest applications of science to agriculture and industry.

It soon became apparent, too, that agricultural research and experimentation would benefit from organization and support. Accordingly, in 1887 the Congress passed the Hatch Act, providing an annual appropriation of $15,000 to each state or ter-

ritory to "aid in acquiring and diffusing among the people of the United States useful and practical information on subjects connected with agriculture, and to promote scientific investigation and experiment respecting principles and application of agricultural science." Thus the Congress, considerably more than half a century ago, recognized the desirability of Federal subsidy of research and development directed toward the general welfare.

As the country has grown, Federal support of various phases of education has expanded and multiplied until today it is bewildering in its extent and multiplicity. What has been the guiding principle that has directed the Federal Government into the several fields of educational activity? President Eisenhower has on many occasions referred to the philosophy of Abraham Lincoln on this point, which is: "The legitimate object of government is to do for a community of people whatever they need to have done, but cannot do at all, or cannot do so well for themselves—in their separate and individual capacities."

It is on this principle that we find the Government directly engaged in providing educational facilities on government-owned, nontaxable land, for Indians in the United States, natives in Alaska, and for peoples of the Virgin and Pribilof islands. We are quite familiar with the extensive educational system that is provided by the Government for members of the armed forces in the service academies, in the war colleges, by extension courses, and by other means. Many agencies provide in-service training for their civilian employees or subsidize their further education in outside institutions. Sometimes the educational activities of the Federal Government are unusual or unexpected. It is a little-known fact, for example, that Gallaudet College, part of the Columbian Institution for the Deaf, incorporated by the Federal Government, is the only college in the world that was specifically established for deaf students. The American Printing House for the Blind, which is supported in part by the Federal Government, supplies educational books, materials, and apparatus for the blind to schools and classes in all the states and territories. One could continue to list at considerable length Federal activities of this type, but these will serve to illustrate that the Government has always conceived that it has a general role to play in the field of education.

Since World War II, however, the Government may be said to have entered on a new phase in its relationship to education. The passage of the Servicemen's Readjustment Act of 1944, which is more familiar as the G.I. Bill of Rights, and the passage in 1952 of Public Law 550, the 82nd Congress, for the benefit of veterans of the Korean conflict, indicated a feeling on the part of the Federal Government that it had a definite responsibility to veterans whose education had been interrupted by these two conflicts. It must certainly be assumed that, in addition to those who completed interrupted educations, many others attended institutions of higher learning who would otherwise have lacked the means to do so.

More recently there has been a growing awareness on the part of people generally that our school system as a whole is not all that it should be. The Federal Government has assumed the leadership in a drive to bring about improvement in our school system through such measures as the School Facilities Survey, the School Construction Bill that was submitted to the Congress in 1955, and the White House Conference on Education that was recently completed in Washington after a year of preparation by the states.

Present Status of Federal Aid

To these concerns has been added another and increasingly urgent one—the concern over the status of education in the sciences. It has been only since World War II that we have begun to feel the pinch in this respect. Up until that time it would not have occurred to anyone that formal, organized action might be necessary if our schools were to produce a sufficient number of persons with highly specialized skills. It is part of our cherished democratic tradition that we permit the law of supply and demand to operate freely with respect to our educational system. During World War II, however, the demand for scientists, engineers, and technicians of all kinds so far exceeded the supply that we were obliged to improvise in many ways. Highly trained scientists were called to serve in multiple capacities, and we found ourselves calling on biologists to perform tasks that were normally carried out by physicists, and using other persons for a variety of tasks other than the ones for which they had been trained. Special weapons produced during World War II created a demand for special skills in operating them; the result was that the armed forces were obliged to send servicemen to school to learn the intricacies of the new equipment.

One might have expected things to return to normal at the conclusion of World War II, but it is apparent now that, as far as the demand for professional manpower is concerned, this has not been the case. Defense needs unprecedented in peacetime, the growth of the atomic energy program, the phenomenal expansion of American in-

dustry, and the onset of automation have all created extraordinary demands for scientists and technologists. There would be no cause for alarm if the supply appeared to be responsive to the demand. We know, however, that this is not the case; and, more serious still, we face a critical shortage of the teachers and facilities that are necessary to meet the needs of the future. The scientific community and the academic world are aware of the extent of the problem. The vital question is, Will the American people respond to a crisis of this type in peacetime, and will they respond in time?

We are fortunate in one respect. During the past decade the Government has found it either desirable or necessary to support education in science to an increasing extent, and the idea is therefore neither new nor unacceptable to the public. Direct assistance took the form of the afore-mentioned G.I. Bill. Fellowships in the sciences have been awarded by the Atomic Energy Commission, the National Institutes of Health, and for the last 4 years by the National Science Foundation. The international educational exchange, which is administered by the Department of State, includes a certain proportion of students who are studying science abroad; but it is interesting to note that the number of foreign students who are studying science in this country under the Fulbright program is considerably greater than the number of Americans who are studying science abroad. In the calendar year 1954, 257 American grantees were studying physical and natural sciences abroad, while 865 foreign grantees were studying these sciences in this country.

The National Science Foundation has recently completed a study, not yet published, of "Federal financial support of graduate and undergraduate students in the sciences." In terms both of numbers of students supported and dollars paid either directly to the students or to their institutions, the figures are not inconsiderable.

In the fiscal year that ended 30 June 1954, the Federal Government gave financial support to approximately 345,000 undergraduates and 47,000 graduate and postdoctoral students. Of the total number of undergraduate students who received Federal support, 83,000 (24 percent) were enrolled in the sciences. Of the total number of graduate students who received support, 23,000 (49 percent) were enrolled in the sciences.

Federal payments to undergraduates (or to the institutions that they attended) totaled approximately $335 million, of which 97 percent was in the form of veterans' benefits. Payments to graduate and postdoctoral students (or their institutions) amounted to approximately $60 million, of which 47 percent was for veterans' benefits. Of the undergraduate total, approximately $82 million (24 percent) went for the support of undergraduate students in the sciences, and $35 million (58 percent) of the total went for the support of graduate and postdoctoral students in the sciences. Note that, out of a total of $395 million, $353 million was provided in the form of payments to veterans for educational purposes.

These figures include more than 5900 graduate students employed as research assistants, who received nearly $11 million in Federal funds in fiscal year 1954. The latter is an important category, for it illustrates how Federal support of research serves not only to further scientific investigation, but also to provide special training in research for science students.

In addition to research assistantships and veterans' educational benefits, Federal aid to graduate students includes training of military and civilian personnel, predoctoral fellowships, postdoctoral fellowships, and traineeships. All these programs serve to increase the number of professional people in the labor force and all are useful and worthwhile. One finds on examination, however, that the majority of these programs were inaugurated to serve varying purposes and that they only indirectly increase the over-all number of scientists and engineers. The Fulbright fellowships are awarded for study in any field as a form of intercultural exchange of persons. The traineeships of the Veterans Administration and the National Institutes of Health are designed to increase the level of competence of personnel in several scientific and technical fields in which there is a current or prospective manpower shortage. Federal personnel, both civilian and military, are given graduate training in civilian educational institutions to improve their ability to perform their duties. Among Government agencies, the National Science Foundation has as one of its primary missions the support and encouragement of policy for education in the sciences. Its fellowship program is designed solely to increase the number of qualified scientists in our society.

Although the Government is, for a variety of reasons, supporting education in the sciences at what appears to be a fairly impressive rate, we must not be lulled into a sense of false security. As the figures cited have indicated, payments to veterans represent a very large proportion of all Federal support of both undergraduate and graduate science students, and these payments will terminate in the near future. Payments to veterans of World War II will cease within a year; and the peak of payments to Korean veterans has already been passed. Cessation of these payments is bound to

strain alternative sources of financial support, and it is possible that the yearly addition to the supply of trained scientific manpower will be decreased to the extent that promising students find it impossible to continue their studies for lack of funds. We cannot afford to face a situation, say 10 years from now, in which we see that we were too late with too little.

Responsibility of the Government

Whether we like it or not, we have been forced into a competitive race with other nations. We cannot ignore the fact that the Soviet Union is graduating almost twice as many technical specialists in certain fields as in the United States. A study that was recently published by the National Science Foundation in cooperation with the National Academy of Sciences–National Research Council reveals that between 1928 and 1954 the Soviet Union graduated about 632,000 professionals in the engineering field, as against 480,000 in the United States during roughly the same period. Agricultural graduates in the Soviet Union totaled about 244,000, as against 133,000 in the United States; and Soviet graduates in medicine outnumbered those in the United States two-to-one. However, the acceleration in the rate at which the Soviet Union is producing technical specialists was not achieved without the disregard of many individual rights and liberties that we consider inviolable.

To hold our own among the nations of the world, the United States must, first of all, maintain the vigor of its national economy. In a technological age, scientists and engineers are vital to the health of the economy. The question, therefore, becomes, What can we do to increase the number of scientists and engineers without doing violence to our cherished principles of individual liberty and without robbing other professions? We have been a little slow to recognize that an educational system that was developed originally to meet the need for doctors, theologians, and lawyers, and later to meet the needs of an expanding agrarian economy, has not kept pace with the technological revolution. We must now face the fact that physics and chemistry may be at least as important to our culture as home economics and wood-working. These truths should force us to take a long, hard look at existing curriculums. Last summer the *New York Times* commented editorially,

"A sense of shock must be felt by any thinking citizen who studies the state of science teaching in our high schools . . . . Only about half of our high schools offer courses in chemistry or physics, and less than 5 percent of our high school students study physics. Less than a quarter of high school students study even elementary algebra. . . . It seems almost incredible that such a situation should exist today. We live in that most remarkable period of human history when science and technology, with mathematics as their foundation, have revolutionized and are revolutionizing our lives at an unbelievable pace."

Although the *New York Times* figures are unintentionally misleading, in that only about half our high schools offer either physics *or* chemistry, and about 23 percent offer neither, the situation is serious enough. The *Times,* which is not given to hysteria, captioned this editorial "An alarming situation" and went on to urge:

"We in this country believe in local control over education, but such a belief is not incompatible with leadership by the National Government in remedying educational weakness. It would seem to be the obligation of our leaders in Washington to inform our citizenry throughout the country of the threat posed by the collapse of science and mathematics teaching in the high schools. On this matter, certainly, there can be no room for complacency."

Many agencies of the Federal Government share the weight of this responsibility. There are the agencies that help finance advanced training in the sciences—the Veterans Administration, the Atomic Energy Commission, the National Institutes of Health, and the National Science Foundation. There are the many educational programs provided by the Department of Defense for both military and civilian employees. There are the intercultural exchange programs of the Department of State. And then there is the Office of Defense Mobilization with special responsibilities for the mobilization and utilization of the nation's manpower, including, of course, its scientific and technical manpower.

We in the National Science Foundation are particularly conscious of the part we have to play because our mission is specifically to support and encourage research and training in the basic sciences. Since the broad outlines of the National Science Foundation program are well known, I shall not review them here. I should like, however, to fill in briefly some of our present plans with respect to science education.

In the first place, let me say that we believe our program of support of basic research contributes in a material way to research education. Since the National Science Foundation entered upon its program of research support, we have awarded 1447 grants, for a total of $17,931,000. Although these figures are not large in comparison with the

support programs of other agencies, we believe that these projects in the mathematical, physical, engineering, biological, medical, and other sciences not only serve to strengthen basic research in the United States but also afford an opportunity to many young research assistants to acquire research training under experienced investigators. We also feel that by helping basic research to expand and grow in the face of the ever-accelerating demands for applied research and development, we are helping to educate the public to its importance and to the need for it in our society.

The fellowship program of the National Science Foundation is now in its fifth year. By December 1955, we had awarded 2723 fellowships, for an estimated total of $6,310,115. It may be of passing interest to note that eight of the present group of fellows are studying with Nobel laureates in science. For the coming academic year, the National Science Foundation is adding to its fellowship program two important new features: a senior postdoctoral fellowship program and a faculty fellowship program. In the senior postdoctoral program, awards will be made to persons who have received their doctoral degrees at least 5 years prior to the time of application. The first awards under this program were made last spring. The objective of this program is to provide opportunities for scientists who have demonstrated superior accomplishments in a special field to become still more proficient in their respective specialties by studying and conducting research in outstanding laboratories.

The purpose of the faculty fellowship program is to improve the standards of college-level science instruction by providing science teachers with opportunities for advanced study and for pursuing courses that will give them a better understanding and knowledge of their respective fields. It is hoped, also, that this program will serve to focus greater attention on the crucial importance of faculty members, who are responsible for increasing our supply of scientific manpower.

Approximately 2.5 million students are now enrolled in the colleges and universities of the United States. It is estimated that the college enrollments will rise to 3.7 million by 1965. We shall need about 50 percent more college science teachers in 1965 than we have today, even if we are simply to maintain the present standards of science instruction. To improve the teaching of science in our schools, we shall need not only more, but better, teachers.

Science in Secondary Schools

But if the teaching of science and mathematics in our colleges and graduate schools faces critical times, the situation in the secondary schools is even more crucial. Here the problems are so numerous and so varied that we may be forced to rethink the whole problem. Some of the problems impinge upon each other. Many educators feel that more important than the question of financing students through college is the even greater problem of identifying and motivating gifted students. The students, in turn, have little chance of being oriented toward science and mathematics if they have no contact with these subjects during their high-school careers or if their teachers are inadequately prepared and uninspired.

I do not mean to imply that all science teaching in secondary schools is of this character. We all know that there are many first-rate secondary-school science teachers who deserve our best gratitude for the fine work they are doing. The point is, however, that even though the demand for science in secondary schools has been small compared with the demand for other subjects, the supply of adequately trained teachers is even smaller. Citizens in their own communities should ask themselves whether in this day and age their local high schools should drop from the curriculum what were formerly required subjects, such as the old sturdy brain-building courses—mathematics, languages, and the natural sciences. One cannot refrain from commenting at this point that in the Soviet secondary schools, mathematics and science courses are stressed extensively, especially in the upper grades, where almost 41 percent of all instruction time is devoted to these subjects. For example, 5 years of physics prior to entrance into institutions of higher learning is required in the Soviet Union, whereas in the United States only about 4.3 percent of all high-school students studied physics in 1954.

Citizens must also face the fact that if they are to attract to and hold in their high schools teachers who are adequately prepared to teach these essential subjects, they must be willing to pay salaries that compare more favorably with those that are now available from industry and other sources. The Federal Government has a proper role with respect to education at the secondary school level, but it can function effectively only if the local communities are willing to face the situation squarely and take the steps that are first necessary if Federal assistance is to be effective.

Although it was planned that the National Science Foundation should function primarily with respect to education in the sciences at advanced levels, we are increasingly conscious of the problem of the secondary schools. The number of things we can do at this level is limited by our terms of reference, by the size of our appropriation, and by

the magnitude of the problem. Among Federal agencies, the Department of Health, Education, and Welfare has primary responsibility for problems relating to the secondary schools. A number of private groups—notably the Science Talent Search that is sponsored each year by Westinghouse, the Science Clubs of America, and, of course, the AAAS—are all making valuable contributions.

The National Science Foundation has worked out its own program, in consultation with these and other groups. In the summer of 1953, we inaugurated a series of summer institutes for college teachers of science and mathematics. These institutes were planned in such a way as to give teachers in the smaller schools contact during the summer months with some of the really first-rate minds in their fields who would bring them up to date with research trends in those fields. The institutes proved to be so successful that we have been expanding the program to include high-school teachers as well. The foundation is sponsoring 20 summer institutes this summer. Nine of these are exclusively for high-school teachers of science; five are for college teachers only; and seven are open to both high-school and college teachers.

In the coming academic year, we expect to inaugurate a high-school science teacher supplementary training program. This program is designed to improve the competence of the individual science teacher by providing him with the opportunity for approximately 1 year of academic study in his field. The program will be undertaken initially in cooperation with two universities and will operate under National Science Foundation grants. Each grant will provide support for the participation of approximately 50 high-school teachers, and each teacher will receive, in addition to the full tuition, a stipend of approximately $300 per month and an additional allowance of approximately $30 per month for each dependent. The two experimental programs will be held at the University of Wisconsin and at Oklahoma A. and M. College.

In addition to the direct and tangible benefits to be derived from such a program, it is also hoped that American universities and colleges will be encouraged to develop and offer, as part of their regular programs, more extensive plans for training in-service and potential science teachers. It may also serve to stimulate secondary-school administrators to provide their science teachers with opportunities for obtaining additional training of the kind that can make them more effective in presenting science to their students, and at the same time serve as an extra incentive to attract capable young people into the teaching field.

Science Curriculums

The matter of science curriculums is, of course, a vital one. The National Science Foundation has sought to support and encourage efforts to improve science curriculums in both the secondary and the college levels. These efforts have taken the form of conferences designed to bring college teachers and eminent research scientists together to consider recent scientific developments and their proper relationships to the teaching of them. Another type of conference that was designed to improve science curriculums brought together, for given fields of science in particular geographic regions, a number of eminent scientists, college teachers and administrators, high-school teachers and administrators, and representatives of state education departments for the purpose of coordinating the region's total science teaching program.

The American Association of Physics Teachers is undertaking a systematic study of curriculums for general physics courses, and the Committee on Educational Policies of the Division of Biology and Agriculture, National Research Council, is undertaking a similar study in the field of general biology at the secondary-school and introductory college levels. The National Science Foundation gave encouragement and moral support to these programs in fiscal year 1956, and it hopes in subsequent years to be able to give financial support to such efforts.

We are aware of the importance, also, of supplementary teaching aids and have been investigating the extent to which television, radio, and motion pictures can be used to enhance the teaching of science, particularly in areas where teachers of science are in short supply. I should not neglect to mention, also, the traveling high-school science libraries, a program initiated this year by the AAAS with support from the National Science Foundation. This program undertakes to bring to students in areas where there is a dearth of books on science a library of 150 books that were selected for the purpose of stimulating an interest in reading science among high-school students, broadening their backgrounds, and assisting those students who are interested in choosing science as a career.

One of the most successful programs that we have supported to date has been the experimental Visiting Lecturer Program that is conducted by the Mathematical Association of America. The Mathematical Association selected five eminent mathematicians who were available most of the academic year 1954–55 for week-long visits to small colleges. The enthusiasm for this plan was so great that the demand for visiting lecturers exceeded the available supply. We are continuing this pro-

gram in 1956 and, in addition, are supporting the American Chemical Society in the conduct of a similar program. We hope that it may be possible in the future to extend it to high schools as well.

Other Efforts

Space does not permit a detailing of all plans and programs that might be grouped together under our Education in the Sciences program. My purpose in enumerating some of these has been mainly to suggest the type of effort that seems appropriate for Federal support and to suggest the kinds of things that can be done by local groups and private organizations without financial support from the Federal Government. One of the most encouraging aspects of our work in this field has been the apparent stimulus it has given to other groups. For example, the Shell Company Foundation, Inc., of New York has announced plans to support two training programs for high-school science teachers at Cornell and Stanford universities, similar to the summer institutes of the National Science Foundation. The University of Minnesota, which has previously participated in our program, will carry on a summer institute for high-school science teachers with support from the Hill Family Foundation. We hope that other groups may be encouraged to enter the field.

In Washington, we have been greatly interested in the Arlington plan, a program that originated in one of the Washington suburbs for the improvement of science teaching in the metropolitan area. It is a purely private and spontaneous movement that was organized to strengthen science teaching, and it has the guidance and assistance for the first year of the National Academy of Sciences–National Research Council. This group has worked out arrangements with eight local universities to offer refresher courses for local high-school science teachers. The group hopes to obtain financial assistance for this project from the Parent Teachers Associations. The group has also inaugurated a summer placement bureau for the purpose of obtaining summer employment for high-school science teachers in industries that are related to their fields.

Conclusions

At this point it seems in order to attempt to summarize our problem in broad terms. The topic *The Crisis in Science Education,* poses a serious social question in the years immediately ahead. In its simplest form it is this: What place do we choose to assign higher education in the up-bringing of our youth? This question is highlighted by the acute situation regarding manpower for science and technology, which is critically needed for the security and the economic strength of the country.

The logical solution would seem to be to work toward a system whereby each person carries through his education to the fullest extent, in accordance with his ability and in the directions where his greatest aptitudes lie. This is entirely consistent with democratic principles, provided that the individual retains his freedom of choice. In accord with our time-honored traditions, the interests of the nation and of the individual are best served when each citizen develops his talents to their highest potentiality. It seems to me that this principle is fundamental and essential.

It is clear from the record that, with respect to higher education, we are falling far short of our capabilities. Our first duty should then be to bring about a general realization of the educational problem and an understanding of the principles that underlie its solution. Scientists, engineers, and educators, therefore have a duty to point out and to demonstrate not only the needs but also the advantages of higher education in general, and of science and engineering careers in particular—advantages both to the individual and to society. If this is done effectively, I believe we should be able to double the number of our graduates in science and to increase substantially the number of engineers. If this is not effective, or if we cannot by this means secure the scientific manpower we need, then we are headed for a crisis indeed.

As for the short-range problem—finding and training scientists and engineers for immediate jobs over the next few years—there is relatively less ground for apprehension but certainly no ground for complacency. This is a situation that is responsive to current demand and active recruiting. Usually such problems get solved one way or another. But the long-range problem is something else again. It is far harder to formulate and undertake, in advance, plans that involve changes in as huge and as complicated a system as that concerned with the education of millions of children. Furthermore, the imperative need to improve the quality of our effort comes at the very time when our educational institutions are sorely beset by unprecedented numbers of students.

I should like to conclude on a hopeful note. We are obliged to admit that we do face a crisis in science education, for we have reached the point where changes must be made. I hope my remarks serve to suggest that there are many things that can be done and many ways of accomplishing

them. The real challenge is to make people generally aware of the extent and gravity of the crisis. Whether we can, and whether they will respond in time, is an open question. The people who established this country and pushed its frontiers across 2000 miles of wilderness were men and women of endurance and tough moral fiber. They were not afraid to expose themselves and their children to the incredible physical hardships of wild terrain and primitive living. We take pride in these people and extol their virtues to each new generation. Now the frontiers are those of the mind. Are we to shrink from equipping our children with the intellectual toughness and vigor that are needed to meet the challenges of a technological age? Or are we to assert that the "hard" subjects, such as languages, and logic, and mathematics, and physics, and chemistry, are too much for them and have no appeal? It would be strangely incompatible with our heritage if we should.

Crater Lake National Park

Crater Lake, one view of which is shown on this month's cover, is the center of a 250-square-mile national park located on the crest of the Cascade Range in southern Oregon. This photograph was taken at noon on an autumn day by Devereux Butcher, Washington, D.C., from Pumice Point looking west along the north side of the lake. The massive rock formation at the right is Llao Rock.

The lake is the remains of a volcano, which volcanologists believe to have been 12,000 feet high. An eruption of pumice and lava that occurred 6000 years ago so hollowed the peak that it collapsed and formed a pit 4000 feet deep. For centuries after the eruption, molten lava seethed on the floor of the pit and many cones formed. After cessation of the volcanic activity, the crater cooled and slowly filled with water. At a depth of 1900 feet a balance was reached between precipitation and loss through evaporation and seepage. The water now is intensely blue, and the surrounding area is world-famous for its beauty. The lake was discovered in 1853 by John Wesley Hillman and others who were seeking a lost mine. Crater Lake National Park was established in 1902.

Mapping the Land

ARTHUR H. ROBINSON

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WHEN the average person in the United States thinks of maps, he is likely to limit his attention to the familiar road map. His reactions are likely to be focused upon the difficulty of properly refolding it, rather than reflection upon its usefulness and seeming ubiquity. He would express amazement if told its relative youth and disbelief at the number of copies made each year—perhaps several hundred million (*1*). Yet, for every road map, there are dozens of other kinds of maps, and ever-present and useful as the road map is, it stands somewhat down the list in terms of the degree to which maps affect human endeavor and accomplishment.

Today the world is in the greatest surge of mapping it has ever known, and the assertion that maps are indispensable to modern life admits of no argument. The comparatively high value of maps has long been recognized by those who use them directly, and the summation of their conclusions reaches an astronomic level. Such activities as highway development, plant location, water provision, flood control, reclamation, and a host of others are literally dependent upon maps. Hundreds of millions of dollars each year are saved—that is, not spent—because of the availability of maps. For example, one of the central states found that about a fifth of its area was not on the tax record simply because deeds had not been written precisely and could not be evaluated until topographic maps became available. The amount involved was more than a million acres, which could represent a considerable tax gain (*2*).

Maps are required for innumerable kinds of activities and are not all alike. The planner in Great Britain who is allocating crop acreages and uses requires a map quite different from the one needed by the highway or sanitary engineer, but in the last analysis all maps are based on the topographic mapping of the land and the hydrographic charting of the sea. It is upon these that man has spent most of his mapping efforts and funds for the last century and a half. The inventory of *what* and *where is it* is a fundamental branch of knowledge and one to which man has been devoting his efforts since before recorded history.

Modern Cartography

The *where is it* has turned out to be a good deal more difficult than the *what*. One can always, or at least most of the time, identify and categorize in some useful manner the objects to be mapped; but to determine their positions with respect to other objects on the spherical earth is not an easy task even when some margin of error is allowed; to do it with complete precision is, as yet, impossible. Nevertheless, man has come a long way since the 3rd century B.C. when Eratosthenes calculated the circumference of the earth on the basis of four assumptions (the errors of which nearly cancelled one another!) and apparently arrived at a surprisingly good estimate. The *what* has involved the accumulation of all kinds of facts, for there is probably nothing known that cannot be somehow mapped. In the early beginning, the cartographer depended on the reports of travelers and ships' captains; later, he went into the field and mapped, and today the air photo has brought the field into the office. Once one knows what he wants to map and where the to-be-mapped items are, he still has a number of important tasks ahead.

One cannot transform a spherical surface into a plane surface without changing fundamental geometric relationships, and transformations in which the geometric properties are systematically arranged are employed. The application of a coordinate grid (latitude and longitude) to the sphere and the "projection" of the grid to a plane also were done before the time of Christ. To make things intelligible and in order to utilize the space as efficiently as possible, symbols and colors must be used, and these, too, are of ancient origin. The oldest map known—drawn more than 4000 years ago—has mountains shown on it (*3*).

The symbolization of the multitude of things that can be shown cartographically has become increasingly complex as the human range of interest and material equipment has enlarged. The only technique of modern cartography that did not have its origin in the ancient world is that of reproduction. The art of printing revolutionized cartography after its introduction in the 15th cen-

tury, and it has been subject to successive revolutions as printing techniques have expanded and improved since then. For example, maps can now be made and reproduced in colors without a single pen stroke being employed anywhere in their "drafting."

These operations of modern cartography (the determination of position, the accumulation of data, the projection, the presentation, and the reproduction) are what the map maker does and what the research cartographer investigates. Additions to the map makers' knowledge of any kind along at least the first four of these general lines tends to make his previous productions obsolete. Hence it is understandable that the modern cartographer spends as much time revising older maps as he does making new ones. The greatest effort, as previously stated, is devoted to the topographic map, the map on which a mile is represented by one-quarter of an inch or more. This kind of map is a relative youth in the old family of mapping, but is by now the most important.

Mapping of the World

It is impossible, of course, to trace the history of topographic mapping and land measurement in detail in this article, but it is instructive to review the highlights, for modern cartographic activity and the rather kaleidoscopic map coverage of the world can hardly be properly understood without a bit of background (*4; 5,* pp. 241–309). The system of measurement of the earth's surface known as triangulation was first put to extensive use in France in the middle of the 18th century. Then, as now, this involved first the measurement, as accurately as possible, of a line several miles long (this is now accomplished by means of precision tapes). Although conceptually it is a simple process, practically it is involved and extremely difficult. From this base of known length, a system of triangles is extended, the relative position of each corner being calculated from observed angles of sight and previously calculated distances. This provides the map maker with a series of points whose relative elevation and horizontal position is known. With this "control," he can go into the field and fill in the intervening spaces with local survey.

Cassini's initial success with triangulation in France was quickly followed by its use in other countries, and by the end of the 19th century most of the European continent had a set of topographic maps or were well on their way to having one. But, as might be expected, there was little or no uniformity among them, and a mapping hodge-podge was the result. The confusion runs the gamut from the geodetic bases of the control to the systems of representation of the terrain and man-made features on the surface, called "culture" by the cartographer. This involves such fundamental

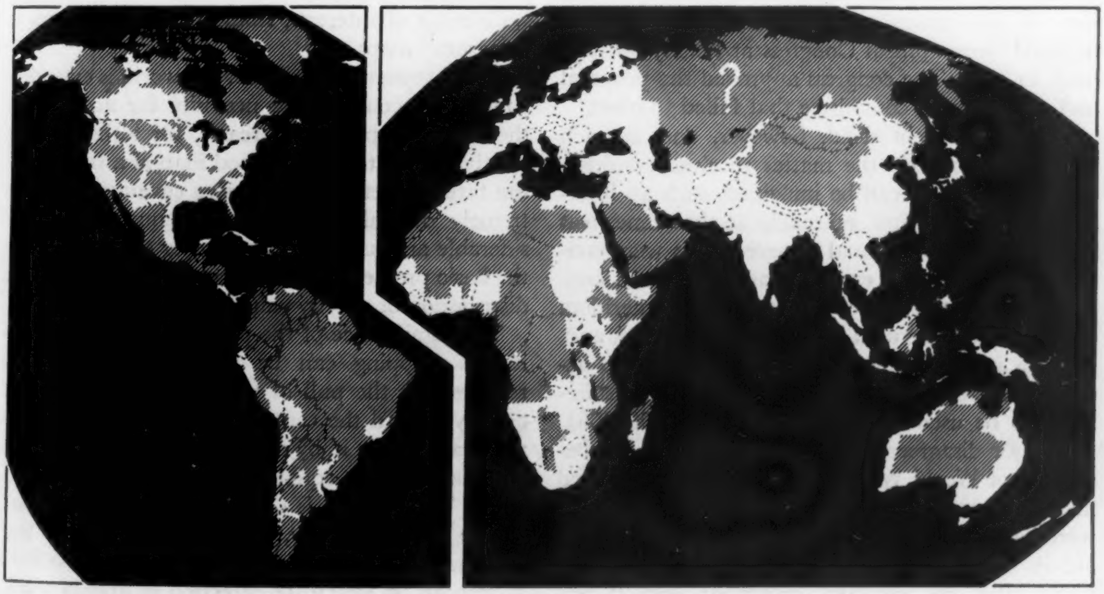

Fig. 1. **Fairly-well topographically mapped areas and very-poorly or not-at-all mapped areas. The former are shown in white; the latter, in gray. Generalized from a variety of sources. Up-to-date information about the extent of mapping in many areas is difficult, if not impossible to obtain—for example, the USSR; consequently, this map should not be considered complete.**

things as the scale of maps, the shape of the earth assumed for the series, the projection system employed to transform the spherical surface to a plane surface, the selection of a meridian from which to reckon longitude, as well as the symbolism of mapped features. For example, more than 15 prime meridians in addition to Greenwich, eight different projections, and seven different ellipsoids have been employed in European topographic mapping. All in all, then, although the countries of Europe were well mapped, Europe *as a whole* was not.

The world situation with regard to topographic mapping is even worse. Whereas Europe is at least covered with some kinds of topographic maps, there are large areas of the earth that have not been mapped on the ground at all. Figure 1 is greatly generalized and shows that the topographically mapped areas are not very extensive (*6*). The picture is constantly changing, and as new maps are made in previously unmapped areas, some other areas are no longer mapped adequately.

Several decades after large-scale mapping was underway, it became evident that complete world topographic coverage was a doubtful possibility. Consequently, thoughts began to turn to the desirability of a smaller-scale compiled map of the earth. Such a map could not have the quality of a topographic map, but would provide rather consistent coverage, and certainly was not an impossibility. The original proposal for some sort of world map based on one ellipsoid and with one system of projection and grid numbering came from Albrecht Penk of the University of Vienna at the fifth International Geographical Congress at Berne, Switzerland, in 1891. The congress approved the proposal and established a committee that failed to meet.

Interest was not dead, however, and at each succeeding congress the matter received considerable attention. As can be imagined, such an international undertaking, especially at that time, was difficult, for international disagreements were continually arising. For example, at the seventh congress in 1899, the French insisted that the meridian of Paris should be used as the prime meridian and, perhaps in retaliation, the English refused to accept the metric system as the expression of measurement to be used on the maps (*5*, pp. 299–306). All major disagreements were resolved by the beginning of World War I. That conflict interrupted international production, but many map sheets were produced by individual nations in order to aid in their war effort. The compilation was revived after the war and continued until it was again interrupted by World War II.

Although it is now underway again, the International Map of the World at a scale of 1:1,000,000 is still far from completed. A notable contribution has been made by the American Geographical Society of New York, which has compiled a set of 107 sheets covering all of Latin America south of the United States (*7*). The need for consistent coverage during World War II caused government agencies to produce similar maps, which are not as detailed. Consequently, there has been completed during the past 10 years, for the first time in history, a complete map of the earth at a relatively large and consistent scale of 1:1,000,000, or approximately 1 inch to 16 miles (*8*).

The present situation of the world with respect to mapping is that coverage of variable quality is complete at small scales, but far from it at large scales. As a consequence, it is to be expected that large-scale mapping will continue to be one of the major housekeeping activities of governments. The need for such maps is continually increasing, for, as the world's population increases and life becomes more complex, more and more planning becomes necessary to insure adequate food supplies and transportation facilities. This means the extension of soil surveys, land-use surveys, water-supply surveys, erosion surveys, population surveys, and a host of others. None of these can be carried on adequately without the basic topographic map as a point of departure. The use of the topographic maps as a base is by no means limited to those activities in which detailed maps are generally conceded to be indispensable; it also serves an important function as a source of information for a wide range of interests, from "marketing" maps to "treasure" maps.

As the topographic map of the world is extended, country by country, the necessity for accuracy in the mapping process increases, for although it is relatively easy to make a good map of a small area, the fitting together of extensive coverage is an extremely difficult problem. Consequently, a considerable amount of effort is being expanded upon the basic problem of the shape of the earth and the distribution of gravity values thereon.

The significance of the precise direction of gravity to mapping can be appreciated when one realizes that the pull of gravity is not everywhere exactly toward the center of the earth. The astronomical latitude is, by definition, the angle between the plane of the equator and the vertical at any place. The vertical is determined by the direction of the pull of gravity, and it is well known that this varies from place to place. The surface defined as a shape on which the direction of gravity would everywhere be the same with respect to the surface is called a *geoid*.

On the other hand, a map must, at least pres-

ently, be the projection of the earth's irregular surface to a more regular surface known as the datum. The datum is defined as a *spheroid* of revolution —that is, a geometric shape that results from self-attraction and the centrifugal force of the rotating earth (*9*).

This relationship is illustrated by Fig. 2. Surface positions are determined of necessity by observation on the geoid, while triangulation is referred to the spheroid; it follows that discrepancies will result unless the relationship between the two is known. These differences are bothersome to the mapper, and some interesting consequences have sometimes resulted. For example, some of the boundaries of western states in the United States are defined by law as following certain meridians and parallels. Establishment on the ground of these regular lines by the early surveys was by astronomical means, and when the lines were later referred to the spheroidal datum of a topographic map they become irregular lines varying as much as ½ mile from the legally defined position.

The modern topographic map is based on triangulation, and its extension over large areas is a major undertaking of modern cartography. So also is the adjustment of older triangulations on different spheroids to a common base. Recently, most of Europe's diverse datums have been adjusted to a common base, and all of Latin America is being joined to the United States and Canadian Systems. The inter-American geodetic survey will provide a framework on which all maps and future surveys of Latin America can be based (*10*).

Making a Modern Topographic Map

The necessary datum and projection having been settled upon, the work of the surveyors and cartographers begins. The United States has been criss-crossed many times by triangulation and leveling lines, and consequently no part of the country is very far from some spot for which a relatively precise position and elevation has been determined. Let us assume for purposes of description that one of the standard "15-minute" quadrangles is to be mapped. This is an area bounded by 15 minutes of latitude and longitude, or an area about 17 miles north-south and somewhat less east-west. This section of the sphere is plotted according to a particular system of projection. On this sheet, which is blank except for parallels and meridians, are plotted the survey positions (bench marks) that have been established by earlier triangulation and leveling. This is the base and the primary control around which will be fitted the mapped information of landforms, woods, settlements, drainage, and the other elements that make up a modern topographic map.

In former times, and occasionally even today, the next step is to send a survey party into the field where, with triangulation and leveling of less precise nature, a large number of additional control points will be ascertained by working outward from the primary control that has already been established. Then with the plane table, alidade, and a few other relatively simple instruments the area will be mapped in the field.

The plane table is what its name implies—a miniature plane that can be moved from place to place and easily set up on a tripod. When set up and oriented at a known position, line-of-sight bearings and scale distances are plotted for a number of visible points. Then, when the plane table is set up in turn at these points, additional sights to other points are made. The places of intersection are the horizontal locations of the points. Objects

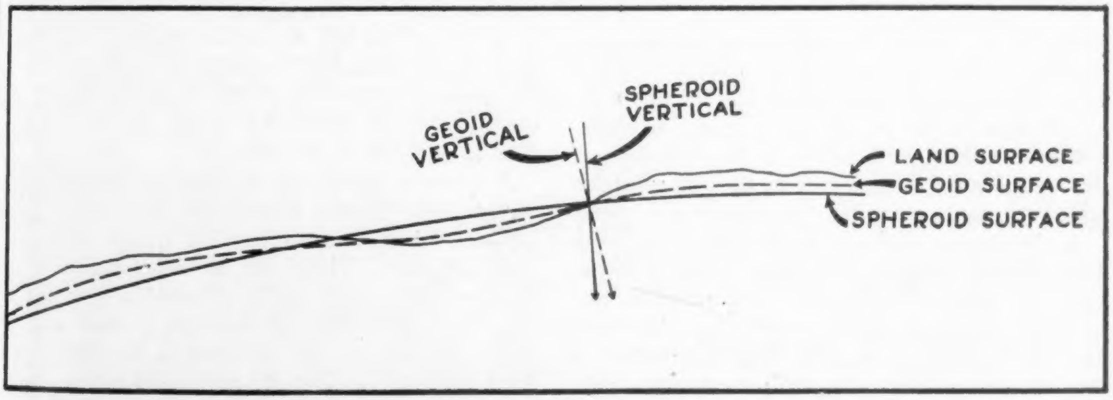

Fig. 2. Diagrammatic representation of the "vertical" difficulties that result from mapping on the relatively unknown geoid with reference to an idealized spheroid. Departures are, of course, greatly exaggerated.

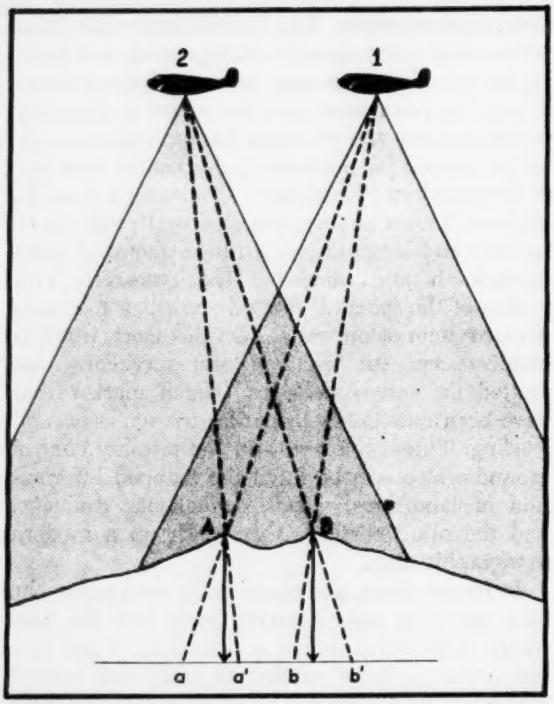

Fig. 3. Successive photos of peaks *A* and *B* appear on the prints as *a*, *a'* and *b*, *b'*. Their datum positions are shown by the heavy arrows.

and information lying between the known points thus established are located by eye or in more rigorous fashion, and ultimately the map is completed. The mechanical aspects of drafting, checking, editing, and printing follow, and the map is finally produced.

The great amount of field work necessary is carried on at the pleasure of the elements; in some areas, the field season is so short and the weather is so unpredictable that it has taken years to produce a map. Time in large measure being the equivalent of money, the field-survey process is expensive. Today the major steps involved in plane table mapping have been replaced by the use of the air photograph, the process being known as photogrammetry. The combination of the technique of photography and the ability to fly has immeasurably added to man's mapping competence and speed.

A photograph of the irregular earth's surface is geometrically complex, for many kinds of distortions are present. Such factors as camera tilt, perspective, curvature of the earth, lens distortion, and others combine to make their rectification to the degree of precision required for mapping a difficult job. Nevertheless these can be accomplished to such a degree that, with few exceptions, it is cheaper and more accurate to do survey work photogrammetrically than it is to do it with field parties on the ground. The widespread use of the air photograph for mapping purposes is relatively young, yet already a considerable portion of the earth's surface has been covered with photographs of sufficient quality to be used for topographic mapping. (*11*). Devices for assisting in the correction of the geometric qualities of the photograph for mapping purposes are constantly being improved, and today there is no guess-work in the process.

The basic control having been established, the next step in the modern mapping process is to plan the photographing of the area. The pictures can be taken at various elevations above the ground, in various seasons, and with a host of other possibilities; the choices are many. After it has been decided at what altitude and under what conditions the area will be "flown", the photographs are made. When the photography has been completed, the results consist of a series of overlapping images. The overlap is about 60 percent; hence any point on the ground is not far from the center of a photograph and is clearly visible on two. The latter is indispensable, for it is this overlap that makes possible the use of photographs for mapping purposes without the necessity of calculating the error of the photo position of every point. Overlapping photographs that have been taken from different positions can be viewed stereoscopically—that is, each eye can be directed to a single picture, and the brain will fuse the two images into a single view that has the appearance of depth or relief.

The basic relationship, greatly simplified, can be seen in Fig. 3. A light ray from a given point—for example, the top of hill *A*—will enter the lens of the airborne camera in one direction from photo position *a* and in another direction from photo position *a'*. When positions 1 and 2 are duplicated in the laboratory and the photographs projected, the two rays will intersect at the relative position at the top of the hill. A vertical dropped from this point to the datum will establish precisely the relative position of the hill. Furthermore the height of the intersection above the datum plane can be used to establish its elevation.

A common method of duplicating the positions of the plane at the instants of exposure in the laboratory is by means of devices known as Multiplex projectors. These can be suspended over a drawing surface and can be adjusted in *x*, *y*, and *z* directions (*12*). Each photograph is made into a small transparency and inserted in the projector. Each projector is carefully positioned so that each photograph matches the ground control points that have already been determined and located on the

drawing surface. This is done by means of a small device that can be positioned over a control point and then adjusted to the proper elevation (Fig. 4).

When each photograph of a strip has been fitted to the control points on the base, then all other parts of the same photographs are, of course, properly oriented, and the exposure positions of the plane in space have been duplicated. This means that all points in the area appear on at least two of the projected photographs and that, at their proper elevation above the datum, the projected images fuse. Then, if red and green filters are inserted in alternate projectors, and if an operator puts on glasses that have one red and one green lens, he will see each feature stereoscopically. After a little practice, this produces a truly remarkable effect. When all other lights are turned off and only the projectors are on, there appears over the white base a small-scale three-dimensional piece of the earth. One can see nothing but this segment, for naturally even the base becomes invisible in the manner that a motion picture screen does when a picture is projected upon it. The opaque adjustable tracing table shown in the center of Fig. 4 is likewise practically invisible.

The small tracing table is also the device by which the information on the three-dimensional visual model is transferred to the base. In the center of the circular flat top is a small pin hole, that is illuminated from below. When the point of light is turned on, it seems to hang in space at a particular level. The entire top of the tracing table with its light point can be raised or lowered. If it is kept at a given distance above the base and moved about, the dot of light seems sometimes to float in space above the model surface and then, if it is moved "into" a hill, it appears to be at a level below the ground surface. The level of the dot is adjustable with great precision. Directly below the floating dot is a pencil in contact with the base. The floating dot can be positioned over a road and brought in contact with it; then by properly raising or lowering it, the dot can be moved along the road and kept in contact with the "surface." The pencil then draws on the base the true orthographic projection of the road. In this way a feature—for example, a road, a stream, or the edge of a wooded area—can be located planimetrically on the base.

When the vertical scale of the visual "model" is known, the floating dot can be set at any desired elevation above sea level. If it is brought into contact with the land surface, and then, at that elevation, moved but kept in contact with the surface, the pencil will trace a contour. The next elevation may be set, the procedure repeated, and the next contour results. The precision with which this can be done depends on a number of factors such as the quality of the projected image and the kind of surface. Sometimes it is very difficult as, for example, over certain kinds of fields that seem to have no surface to them at all. Usually, however, most of the surfaces are clearly defined. It is an amazing experience to see the dot go "down" a chimney, and the conditions that allow such precision are not unusual at larger scales.

The Multiplex procedure for photogrammetric map making has certain drawbacks. The most important among them is that, in order to project the pictures, it is necessary to reduce them to small transparencies. As a result, when they are projected they lose some definition. Consequently, they are not so easy to work with, and occasionally one is unable to define positions with sufficient accuracy; therefore, other types of instruments have been developed with which it is easier to obtain the desired accuracy. Each of these stereoplotters operates on essentially the same basis—the utilization of a floating point over a stereo pair.

The limits of vertical accuracy for United States contour maps are rather high and are, briefly stated, that 90 percent of the readings from a contour map should be within half the contour interval (*13*). The standard United States contour interval is 20 feet, and many maps have a smaller interval. The horizontal locations are to be within approximately 40 feet of the actual ground position, which on the very large scale of 1:24,000 amounts to about 1/50 inch on the printed map. The photogrammetric methods now in use enable the mapping authorities to meet these standards, but some methods and devices are more efficient for one type of terrain or scale than for another. Consequently, no single system is universally in use. It should also be pointed out that the science of photogrammetry is still young and that improvements are constantly being made.

After the map has been compiled in pencil, it is inked and prints are made for field checking. These prints are taken into the field by individuals who perform a variety of checking functions. Perhaps the operator of the stereoplotter was unable to see clearly an area and it must be put in by plane table methods; or perhaps a contour became lost in a particularly difficult region. Names need to be selected, spellings checked, and a host of other relatively small but vital operations require completion before the map is ready to be drafted.

Preparing the Map for Printing

The revolution in surveying techniques that was brought about by the inventions of the airplane

Fig. 4. A battery of Multiplex **projectors** in position **over a drawing** surface. The **operator is using** the adjustable **tracing table** that carries **the point of** light. [Courtesy **U.S. Geological** Survey.]

and photography is no greater than the revolution that has taken place in the technical methods for preparing a map to be printed. A draftsman of the 1930's would find procedures very different in many modern-day drafting rooms. If one goes back even further, he will find that during the past 100 years drafting and printing have been subject to continuous revolution, especially because, in this field also, photography has changed things completely.

For example, a century ago when good topographic maps were being made they were engraved in metal; 25 years ago they were drafted in ink; today it would not be unusual for a map to go from the field checking stage to the printed map without any ink being put to paper. To be sure, the older techniques are still in use in various parts of the world. Nevertheless, an employee of 30 years' standing (frequently literally) in the drafting room of the U.S. Geological Survey finds that what he is doing now is likely to be completely different from what he did when he began.

Most topographic maps are printed in several colors so that the reader can keep track of the various categories of information. The colors ordinarily used are black, blue, and brown. Occasionally extra colors such as green and red are also printed. Each color requires a run of the paper through the press and therefore calls for a different printing plate. Thus, each printing plate requires a separate drawing. All the drawings for each map must match closely. The term for this in printing is *register*. As can well be imagined this is one of the greatest problems in map reproduction, for not only must the drawings all fit one another when made, but each must be printed in exactly the right position by a high-speed press.

One hundred years ago good registry was not particularly difficult, for the image to be printed was engraved in metal which kept its shape; but as copy for the printer was put on paper to be lithographed or photoengraved, it became a problem since paper expands and contracts with changes in humidity and temperature. With the development in recent decades of various kinds of plastics (especially Vinylite) that are dimensionally stable, plastics have been adapted to the requirements of cartography. Although they are not exactly like paper, they can be used for drafting, and good registry can be maintained.

Each successive printing is made from a printing plate. The printing plate is made photographically by sensitizing the metal plate and exposing this light-sensitive surface to a negative in essentially the same way that ordinary contact prints are made of snapshots. Certain kinds of film are now available that maintain their shape quite well, but for exact work the negative may be of glass. Even with a glass negative and a metal printing plate there is a possibility of misregister in the copy or drawing that is to be photographed. Partially as a result of trying to control more closely the register, a new

process known as *scribing* has been developed in the last few years (*14*). This makes any drafting unnecessary after the compilation stage, except perhaps the lettering of names.

The scribing process may be briefly described as follows. After the compilation sheet has been field checked, the line work of the entire compilation is transferred to glass plates or dimensionally stable plastic sheets. This is done by using an emulsion that is translucent enough to see through when it is placed over a light; on it the compilation appears either in positive or negative form. This ghostlike surface is then covered with a not-too-hard and not-too-soft coating that is also translucent enough to allow one to see the map image, but of such a nature that it will stop the passage of the intense actinic light that is used when a sensitized printing plate is exposed.

The coating is then "engraved" or scribed with various kinds of tools. The operator merely removes the coating cleanly whenever he wants a line or space to be printed. The scribed image then can be used directly as a negative—that is, a plate can be made from it without going through the usual camera-negative stage that has heretofore been required. As many duplicates to be scribed can be made as there will be printing plates. Since all the map material is properly registered on the compilation sheet, each of the copies is scribed only for those elements that are to be printed in a single color. Register will be nearly perfect.

Although scribing may seem to be a technical detail in the reproduction procedure, it promises to be another in the continuing series of revolutionary changes in the cartographic process. Whenever it has been used, it has resulted, among other things, in better quality, faster production, more uniformity, and a saving of upwards of perhaps 25 percent or more in the general drafting cost (and production time) of a topographic map. The ordinary ink drafting of the separate plates for a map took an average of more than 525 hours in the U.S. Geological Survey; when it was done by scribing, this was reduced to about 400 hours (*14*). Additional savings result, of course, because there is no need to use a camera and prepare an additional negative, since the scribed plate *is* the negative.

The separation drafting or scribing needed for the different printing plates of a topographic map is shown in Figs. 5 and 6, which are small portions of the Cumberland (Md., Pa., W.Va.) quadrangle of the U.S. Geological Survey. Although both plates are reproduced here in black, the convention of

Fig. 5. (Left) **Black printing of a portion of the Cumberland (Md., W.Va., Pa.) quadrangle of the U.S. Geological Survey. All the control, culture, projection, and border information appears on this printing. Fig. 6. (Right) Brown printing of a portion of the Cumberland quadrangle showing contours and spot elevations. [Courtesy U.S. Geological Survey.]**

Fig. 7. A different part of the shaded relief edition of the topographic map shown in Figs. 5 and 6. The shading is printed from three additional plates in different colors. The uplands are brownish and the lowlands greenish in tint. [Courtesy U.S. Geological Survey.]

color use is well established. Black is commonly used for all the cultural information such as roads, names, buildings, and other similar man-made features. Brown is reserved for contours and such other hypsometric data as are presented—for example, elevations of hill tops and road corners. Two additional colors, requiring two additional plates, are also used in printing the Cumberland quadrangle. Blue, as may be expected, is employed for hydrographic features, and red is added for road and settlement information.

In order to enhance the visual characteristics of the terrain, some quadrangles have the additional element of shading applied. After long experience, it became evident that there is a fundamental problem involved in symbolizing the terrain on a typographic map, one of the main purposes of which is, of course, to present the nature of the land surface. Topographic maps are used for a variety of purposes that range from serving the needs of the engineer who must make measurements on the map—for example, for fill or drainage—and the interested citizen who wants to know what the land is like.

The difficulty arises from the fact that the most commensurable method of delineating the land (contours) is the least visual, while the most realistic or visual (shading) is the least commensurable (*15*). Consequently, the topographic maps of the world range from one extreme to the other. In recent decades, it has been generally agreed that the element of commensurabilty is paramount in importance, and the problem has thus become one of how to combine shading with contours. This is nothing new insofar as foreign topographic maps are concerned, but it has not been generally done in the United States until comparatively recently. Now, many of the quadrangles produced by the U.S. Geological Survey appear in a conventional edition and also in a shaded relief edition.

The shading is done by a competent artist who paints a chiaroscuro rendering of the terrain that is then printed in several successive impressions on the standard topographic map. This cannot, obviously, be done by the scribing process. The shading adds substance to the land, and the present shaded-relief maps of the U.S. Geological Survey are among the most expressive topographic maps made anywhere. Figure 7 is a portion of the shaded relief edition of a topographic map. Although this portion is taken from the same quadrangle as Figs. 5 and 6, the Cumberland quadrangle, the portion selected is a different one. Obviously, the black and white reproduction here does not have the graphic quality that the multicolor original does. Certainly the shaded relief maps being produced now are works of art. At 20 cents apiece they are, without doubt, one of the greatest bargains available today.

Revision of Topographic Maps

This brief review of some of the aspects of topographic mapping would not be complete if it were not pointed out that the cartographic portion of the national housekeeping function, like the job of an individual housewife, never ends. The character, the utilization, and the occupancy of the home of man is always changing, in some places more rapidly than in others, and it is an annoying fact that a topographic map is practically out of date before it is printed. Many of the smaller countries of the earth have mapped their national areas several times. On the other hand, some countries, either because they started late or because they contain a vast territory, have never been able to complete the first mapping, and they find themselves mapping new areas and revising old maps at the same time. Such a country is the United States. The revision of maps is an important task in order that a growing "community" does not find itself with an out-of-date "property description."

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Compared with the medieval university, the contemporary university has developed the mere seed of professional instruction into an enormous activity; it has added the function of research; and it has abandoned almost entirely the teaching or transmission of culture.

It is evident that the change has been pernicious. Europe today is taking its sinister consequences. The convulsive situation in Europe at the present moment is due to the fact that the average Englishman, the average Frenchman, the average German are uncultured: *they are ignorant of the essential system of ideas concerning the world and man, which belong to our time. . . . This new barbarian is above all the professional man, more learned than ever before, but at the same time more uncultured—the engineer, the physician, the lawyer, the scientist.*—Ortega y Gasset, *Mission of the University* (Princeton University Press, 1944), p. 57.

Colorado Dam Controversy

ANGUS M. WOODBURY

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A PLAN for the development of the Upper Colorado River Basin for water conservation by use of reservoirs has recently been passed by Congress. This article is an attempt to analyze the controversy that preceded its passage.

The Colorado River rises in the Rocky Mountains of Colorado and western Wyoming, flows across southeastern Utah and northwestern Arizona, and enters the Gulf of California in northwestern Mexico. Its basin encompasses about 250,000 square miles, roughly one-twelfth of the United States.

It traverses a large area. The river's mouth in the Gulf of California lies more than 900 miles south of its Wyoming origin and more than 500 miles west of its Colorado headwaters. Meandering southwestward more than 1700 miles, the river flows through more than 1000 miles of colorful gorges and canyons, descending more than 10,000 feet to the ocean.

This is not extraordinary or unique. Other rivers are longer, drain larger areas, and carry larger volumes of water. However, few large rivers have a steeper gradient, and few traverse more canyons or have a more varied physiography. Why, then, is the Colorado River proposal so controversial?

The reason is principally an economic need for water. Competition for this great water supply is tremendous and will, by all odds, increase. The river flows through a continental interior desert region where water is in great demand. This basic competition of water demand is often lost in the maze of other considerations. The basin has spectacular scenery: thousands of miles of canyons, side canyons, gorges, cliffs, pinnacles, and other weird erosional forms—all made esthetically brilliant by the basic colors of exposed rocks; varied vegetational types from dense forests to desert shrubs; diversely rich archeological remains, as ruins of cliff dwellings, pueblos, and lesser structures; scientifically important geologic formations ranging from Archeozoic to Eocene; and an infinite variety of physiographic forms—valleys, canyons, mesas, plateaus, mountains.

Haggling over the ownership of the Colorado River water follows naturally from the great demand for its use. I learned early of the ruthlessness of competition for water. As a boy of ten I accompanied my father from our home at Saint George, Utah, in the Virgin River Valley, into the wilds of the "Arizona Strip" at "Parashont," near Mount Dellenbaugh, where a huge roundup of cattle was in progress. This plateau overlooks the heads of the numerous cliff-sided canyons leading steeply down into the great bend of the Colorado River before it enters Lake Mead.

Water was scarce—it was inadequate to supply livestock needs on the huge expanses of open range on the "strip." As a result, livestock were concentrated during the hot dry summer around the water holes and springs, thereby accelerating overgrazing around the water supplies. When I was there (1896), because of a severe drouth, many sources of water available in ordinary years were dry.

The crowding of cattle around the permanent water supplies made it necessary for them to travel farther from water to get necessary food. Areas around the Parashont water were dust beds. Owners of water in some cases guarded their supplies and gave preference to their own cattle. It did not take long for others to die of thirst. No wonder my father went out of the cattle business when he found only two of his herd left.

Arid Lands

This incident is symptomatic of arid lands, wherever water is scarce. At the Arid Lands meetings of UNESCO and the AAAS in New Mexico in April, 1955, it was estimated that one-third (32 to 35 percent) of the land of the earth receives

an inadequate natural water supply, usually less than 15 inches of precipitation. A large part of this land receives less than 10 inches and some of it less than 5 inches; these are usually the deserts.

The usual effect of restricted water supplies is to limit the size, the kinds, and the numbers of plants that can grow in such areas. The animals associated with the plants are usually inconspicuous and adapted to live with the scrubby plants. The fauna of vertebrate and invertebrate animals is usually more rich and varied than strangers to the desert anticipate.

The precipitation of arid lands is usually inadequate to produce any runoff, either underground in the form of springs or overground in the form of streams, except floods from quick heavy showers in which the water cannot soak into the ground as fast as it falls. Additional water, if any, usually comes in the form of streams from distant mountains or regions of heavier precipitation (usually more than 20 inches) where the soil cannot hold all the water that falls.

Lands are arid from a variety of causes but mainly because of the wind patterns of the earth, which bring prevailingly dry winds to certain areas. The warm air of the tropics which rises, cools, loses its moisture, and descends in the subtropics is a drying wind and usually brings no rain. It is the cause of such dry climates as those found in the Sahara in Africa and along the United States-Mexico border in North America. Additional deserts are found where winds blow offshore or where lands lie in the rain shadow of mountains that inshore winds pass over.

In arid lands, the rain that falls usually soaks into the soil but goes into the ground only as far as the soaking penetrates. Thereafter, water is either evaporated from the surface of the ground or pumped out of the soil by plants. Many desert plants have huge root systems spread through large volumes of soil to gather enough water to maintain a small amount of foliage above the ground.

There is usually a hardpan of impervious precipitate at the bottom of the soil soaked by the water, unless there is underground water from distant sources that prevents the hardpan from forming. Under these conditions the subsurface water may be drawn to the surface and evaporated, leaving surface precipitates. Such soils usually require irrigation or other special treatment to make them productive.

Such marginal soils of deserts are not usually utilized until population pressures make it worth the effort; hence dense populations usually accumulate in less marginal places than they do in deserts. However, if water is supplied artificially to arid lands, most of the marginal handicaps are eliminated and populations can increase, usually to the limits set by the water supplies.

At the Arid Lands meetings, it was estimated that the world population doubled from 100 million to 200 million in the first thousand years A.D., more than doubled from 500 to 1200 million in the 200 years from 1650 to 1850, and again doubled from 1200 million to 2400 million in the century from 1850 to 1950. If this trend continues, much higher increase rates can be expected in the future, perhaps another doubling by the end of this century.

Population trends in the United States are not exact duplicates of those of the world, but the same general trend of rapid population increase is obvious. It has been estimated that the population of the United States, at present trends, will jump from 165 million in 1955 to 228 million in 1975 (*1*), about the time that the Colorado program would be effective. The great tide of migration sparked in former generations by the slogan "Go West, young man" is now being stopped by the Pacific Ocean.

This population tide passes over great wide-open spaces of interior arid lands and deserts to pile up against the Pacific Coast. Many of the passers-by would willingly stay and face the desert climate if there were more water. Many people love the extremes of the desert climate; in fact, they prefer it to the monotonous monoclimate of the coast.

When the white man settled the interior, he first took possession of the areas at the edges of the valleys where streams of water debouched from the mountains and made irrigation easy. Here, he made irrigated oases at the canyon mouths which later grew from farms into towns and cities.

As populations grew and more water was needed, cooperative activities of local communities made possible diversion works on a larger scale that led water onto higher benches farther from the stream. A new era arose late in the last century when the easy projects had been developed and larger and more expansive works that required more than local cooperative capital were needed.

This was an era of private enterprise, in which people with vision enlisted investment capital in relatively large projects such as some of those along Snake River in southern Idaho. Such projects required not only engineering to provide dams and canals to deliver water to the land but also financing to control and distribute the land for farms, towns, and cities. In the West, most of the new land belonged to the Federal Government.

The need to control lands under such projects led to the passage of the Carey Act in 1894, by which the Federal Government granted 1 million

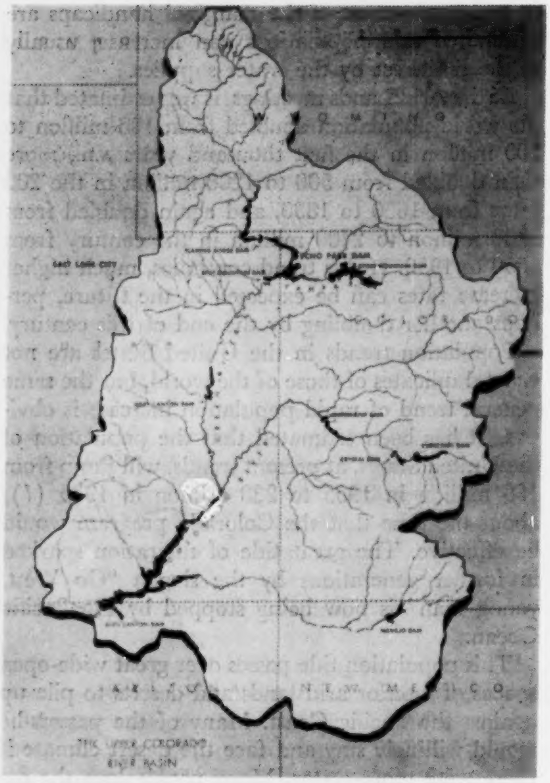


Fig. 1. Map showing the upper basin drainage of the Colorado River and ten proposed dams and reservoirs. [From "Why Echo Park Dam must be stopped," courtesy Council of Conservationists, 161 E. 42 St., New York 17].

acres of desert land in certain states of the West for this purpose. These lands were to be reclaimed by irrigation under direction of the states and disposed to the settlers in small tracts. These private enterprises were largely experiments in inefficiency and many of them ended in financial difficulties. The engineering was not always good, the land potentials were not thoroughly studied, financing plans were usually inadequate (projects often cost much more than estimated), and people were saddled with burdens that should have been spread over two or three generations. A project on the west shore of Utah Lake bankrupted the sponsors; one in southern Idaho settled its million dollar debt for 25 percent; another one on a $1 million investment cleared $1500.

Reclamation Movement for Water Conservation

It was against this background of dissatisfaction with private enterprise not only by the financiers but also by the home owners and farmers that the U.S. Reclamation Service developed. Established as a Federal agency in 1902, the Reclamation Service soon developed comparatively safe engineering practices, equitable plans for distributing land and water, and methods of distributing the costs of expansive developments over longer periods of time (more generations) or over larger segments of the population (public charged with flood control). In essence, the Federal Government loaned its credit for the development of reclamation projects in order that the costs might be repaid out of production from the water and lands reclaimed. For example, nearly all of the costs of the highly controversial Strawberry Reservoir project for Utah County have been repaid while at the same time the areas covered have become very highly developed and prosperous.

In the beginning, the Reclamation Service had a "turnover" reclamation fund, but by 1916 it proved inadequate and funds were provided by the Congress thereafter. At first the duties were primarily by irrigation of arid and semiarid lands in 16 western states. Later, however, its responsibilities embraced multi-purpose water conservation, including hydroelectric power, domestic and industrial water supplies, flood and sedimentation control, fish and wildlife protection, recreational facilities, as well as irrigation and other benefits.

Attention was early turned to the problem of harnessing the Colorado River, but legal and political difficulties beset the way, particularly the problems of distribution of water among the states of the Colorado Basin and Mexico. By 1922, a compact was prepared proposing to allocate 8.5 million acre feet of water to the lower basin, including parts of Arizona, California, Utah, New Mexico, and Nevada, and 7.5 million to the Upper Basin, including parts of Utah, Wyoming, Colorado, Arizona, and New Mexico.

After the compact became effective (1928) in all states but Arizona, the Congress authorized the construction of the Boulder (now Hoover) Dam to serve the Lower Basin. At that time, a complete development of the river was envisioned. The U.S. Geological Survey through its Water Supply Branch had, as early as 1916, published its Bulletin No. 395 outlining its ideas of the utilization of the Colorado River. This was followed during the next 14 years by three additional papers, Nos. 556, 617, and 618, giving details of development possibilities, divided into three segments, the Green River Basin, the Colorado above its junction with the Green, and the Colorado below its junction with the Green (Fig. 1). These papers set the perspective and gave engineering data from which a program could be evolved.

The Hoover Dam, completed about 1938, was

followed by auxiliary dams farther down stream, including the following: Davis Dam which was built to control the outlet water from the Hoover power plants; Parker Dam, which diverts water through the Colorado River Aqueduct and delivers water to Los Angeles, San Diego, and about 20 other California cities; Imperial Dam with its immense All-American canal, which delivers water to the Coachella and Imperial valleys near the Salton Sea, where new land is rapidly being brought under cultivation; and Morelos Dam in Mexico.

Upper Basin developments were not undertaken concurrently with the Lower Basin projects even though plans and programs had been under consideration for many years. The program was carefully considered not only by the engineers with the Reclamation Service know-how but also by successive levels of administration until it finally won approval from the Budget Director and the President. It was then started on its stormy road through Congress.

Forest and Park Conservation

The reclamation program was begun and developed about the same time as other conservation programs, particularly those of national forests, parks, and monuments. Although sporadic beginnigs of conservation movements were not uncommon during the last quarter of the 19th century or even earlier, the big movement was motivated by President Theodore Roosevelt near the beginning of this century. It emphasized a change-over in control from despoilers of the land to planned management of national resources.

The U.S. Forest Service was established in 1905, and the U.S. National Park Service was established in 1916–1917. The national forests were firmly established on a foundation of planned and controlled use; the national parks on a basis of preservation of natural conditions. However, the forests were tied in closely with grazing use, and about three decades later a Grazing Service was established. Although national parks and monuments were dedicated to preservation of natural conditions, they have become increasingly associated with the idea of use for recreation purposes.

In order to provide access to these natural phenomena of parks and monuments, it has been necessary to build roads and trails, hotels or lodges, museums, water supply facilities, telephone lines, offices for workers, homes for employees, and other appurtenances necessary for human communities. To regulate their use, rangers have been employed to manipulate traffic and enforce regulations, naturalists to inform and entertain the people, administrators to supervise operations, and architects to plan and builders to construct the necessary facilities.

The magnificent job done by the National Park Service is attested by the ever increasing numbers—thousands, hundreds of thousands, millions—of visitors using the national parks. Such popularity threatens the tenet of preservation of natural conditions. The more the parks are used, the more the natural conditions are sacrificed to provide for more use. But such popularity brings with it support for the program. More people want more places to visit, either more facilities in existing parks and monuments or new areas for additional parks or monuments.

The park and the reclamation movements developed more or less together. Both of them were concerned with the Colorado River Basin. While plans were being made for dams and reservoirs in the canyons by the Reclamation Service, parks and monuments were being established by the Park Service. Of particular concern here are Grand Canyon, Zion, and Bryce National Parks and Dinosaur, Rainbow Bridge, and several other national monuments. The National Park Service made a special study of the Colorado River Basin.

In most cases, the two programs were made to harmonize without difficulty, but in one case at least there was a definite conflict. Both wanted the canyons of the Green and Yampa rivers in northwestern Colorado, the Reclamation Service for reservoirs, the Park Service for an extension to Dinosaur National Monument.

It should be made clear at this point that the Park Service claims to these canyons had nothing to do with the dinosaur fossils, which are not in any way concerned in the conflict. The fossils themselves are on the mountainside outside the canyons, and there is no danger whatever of their being covered by water of the proposed reservoirs. Instead of making new monuments of the canyons, the Park Service added them to Dinosaur National Monument, primarily for administrative reasons.

Controversy

The competition between the Reclamation Service and the National Park Service for these areas has been keen for many years. The accompanying map (Figs. 2 and 3) shows the background for the disagreement. The lands along the streams of the Green and Yampa rivers shown in black represent federal withdrawal for power purposes made between 1904 and 1925 inclusive; they take priority over the extended monument. The original 80-acre tract of Dinosaur National Monument, which was

Lands Withdrawn for Power Purposes Within Dinosaur National Monument

Legend	Power Site Withdrawals	Date of Approval	Still in Effect
PSR	Reserve No. 5	May 26, 1909	Yes
Power Site Reserve	Reserve No. 42	Aug. 27, 1909	Yes
	Reserve No. 121	March 10, 1910	Yes
PSC	Reserve No. 721	July 11, 1919	Yes
Power Site Classification	Reserve No. 732	Dec. 27, 1919	Yes
	Classification No. 3	May 17, 1921	Yes
Blue Area	Classification No. 60	Feb. 21, 1924	Yes
Dinosaur National Monument	Classification No. 87	Feb. 14, 1925	Yes
Black Area	Classification No. 93 (Echo Dam)	April 16, 1925	Yes
Lands withdrawn for power purposes	FPC Project No. 524	Aug. 4, 1924	Yes

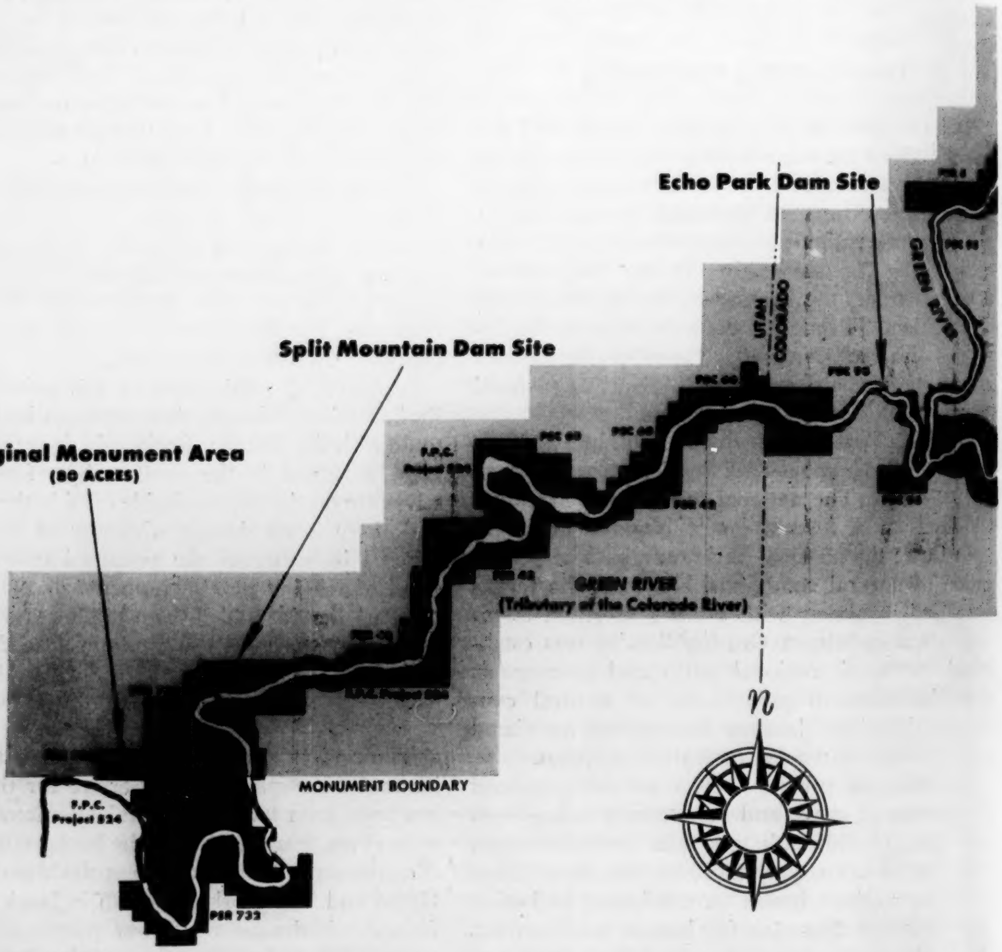


Fig. 2. Map showing original Dinosaur National Monument (left), lands withdrawn for power purposes (black), and areas included in the Dinosaur National Monument extension in 1938 (gray). [From *Colorado River News*, published by Colorado River Grass Roots, Inc. (1955)].

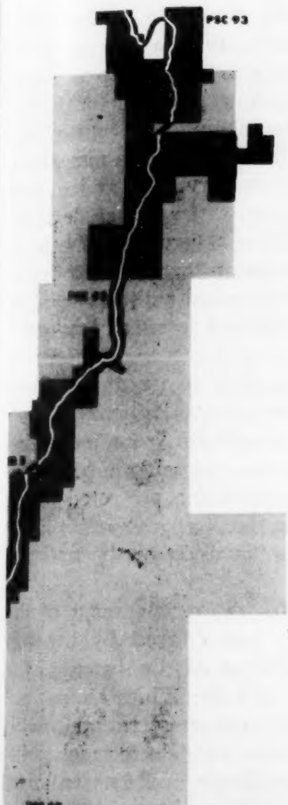
DOCUMENTS SHOW ECHO PARK AREA RESERVED FOR POWER USE

Shown in black on the accompanying map are the 11 power and reclamation site withdrawals made from 1904 to 1925 in what is now Dinosaur National Monument. These land reservations —**specifically including the Echo Park dam site**—were made by the Secretary of the Interior or by the Federal Power Commission for the purpose of water and power development in the public interest. These reservations are still in full force and effect today, according to the chairman of the Federal Power Commission and government authorities who have checked the documents in the case.

Thus, there is no question of the dam site invading the national monument—in fact it is the other way around actually. The reclamation site has first and prior rights legally.

Documents accepted recently by the House and Senate Committee hearings on the Colorado River Storage Project show that the National Parks Service and the Secretary of the Interior twice —once in 1934 and once in 1935—requested release of these power and reclamation reservations but that both requests were rejected by the Federal Power Commission.

Following is the direct quotation of the FPC on this matter at that time: ". . . Giving due consideration to the prospect that some time may elapse before this power is needed, **the Commission believes that the public interest in this major power resource is too great to permit its impairment** by voluntary relinquishment of two units [Echo Park and Blue Mountain dam sites] in the center of the scheme. The Commission will not object, however, to the creation of the monument if the proclamation contains a specific provision that power development under the provisions of the Federal Water Power act will be permitted." This specific provision was included in the presidential proclamation of 1938 which expanded Dinosaur National Monument from 80 to 203,965 acres and took in the above-mentioned dam sites.



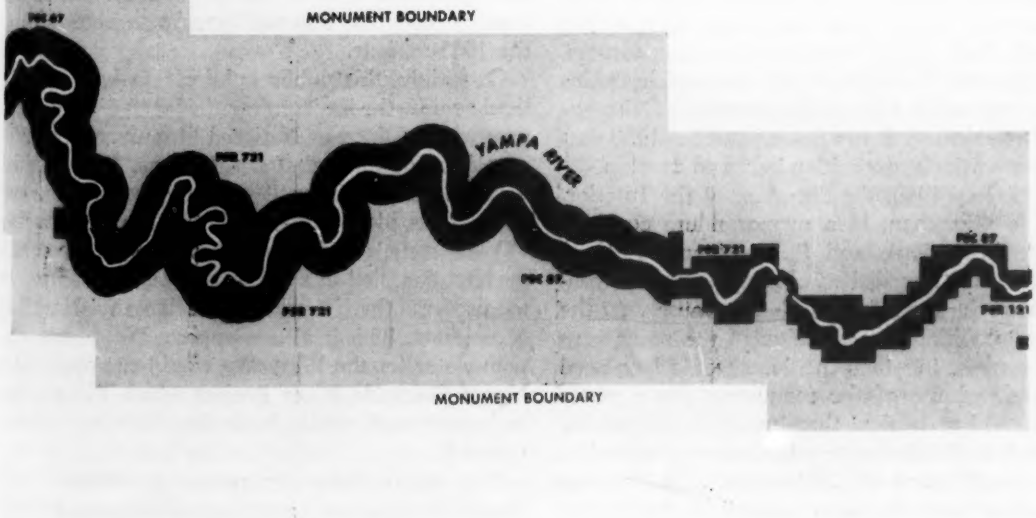


Fig. 3. Continuation of Fig. 2 (eastern portion).

established by Presidential proclamation on 4 October 1915, had priority over the Power Site Reserve No. 732 of 27 December 1919, which surrounded the monument. However, the area shown in gray, which represents the expansion of the Dinosaur National Monument by Presidential proclamation on 14 July 1938, was antedated by all the power site withdrawals that are shown in black.

Two important restrictions not found in other national monument proclamations were incorporated in the expansion proclamation of 1938. The President stated ". . . now, therefore, I . . . do proclaim that, *subject to all valid existing rights,* the following described lands . . . are hereby reserved . . . . The Director of the National Park Service . . . shall have the supervision, management and control of this monument . . . except that *this reservation shall not affect the operation of the Federal Water Power Act* of June 10, 1920 (41 Stat. 1063), as amended. . . ." (italics mine).

At the time of this proclamation, these restrictions were well understood by officials of the National Park Service (*2*). A letter from A. E. Demaray, acting director of the National Park Service, to the Federal Power Commission, dated 9 August 1934, referring to the proposal for enlarging the monument, recognized the conflict of interest in the Echo Park Dam site and the Blue Canyon Dam site and then remarked "Such an area would be established by Presidential proclamation which would exempt all existing rights, and a power withdrawal is of course an existing right."

Until the beginning of World War II, the Reclamation Service with the cooperation of the National Park Service continued making surveys, building roads, drilling dam sites, and making plans for the reservoirs within the canyons of the extended monument. It was not until about 1950 that the conservationist opposition began to develop.

On 27 July 1950, the Secretary of the Interior, Oscar L. Chapman, in a memorandum concerning the Echo Park and Split Mountain dams, stated, "I am impelled . . . to approve the completion of the dams in question, because . . . the order establishing the extension of the monument in the canyons in which the dams would be placed contemplated use of the monument for a water project, and my action, therefore, will not provide a precedent dangerous to other reserved areas."

Senator Watkins of Utah stated (*2*) "Similar conclusions have also been reached by the present Secretary of the Interior, Douglas McKay, and by President Eisenhower. . . ." If this were all of the controversy, the matter could be readily settled on the basis of these historical and legal perspectives. Many people, however, are not willing to settle the matter on this basis.

Conservationist Resistance

A large segment of the American public is devoted to the ideal of conservation of renewable natural resources under management so planned that a continuing yield is provided and yet the resources are preserved unimpaired for future generations. This ideal has its application in many lines of human activities (soil conservation, agricultural practices, livestock rearing, water power development, flood control, wildlife refuges, water conservation, arid land reclamation, and many others) but it is especially well organized and developed in public support of the national forest and national park systems.

Conservationists in general have been so solidly behind the movement to protect the national park system against encroachment by "commercial interests" that the Congress has seldom permitted the building of reservoirs in the protected areas. This support is so strong that Congress is not likely to yield to promiscuous "invasion of the national park system."

When the program for the development of the Upper Colorado Basin was cleared by the top echelons of the Department of the Interior, the Bureau of the Budget, and the White House and was passed by the Senate, the conservation organizations became alarmed and brought so much political opposition into the House of Representatives that the proposal was not brought to vote during the 1955 sessions.

Ostensibly, this public opinion was being mobilized against the impoundment of water in the canyons within Dinosaur National Monument. In a recent issue of the *Salt Lake Tribune,* Fred Smith, director of the Council of Conservationists, explained his idea of the basis for the controversy (*3*). He stated: "The conservationists of the country have supplied in a gratifying way the campaign to prevent the invasion of Dinosaur National Monument. This is all we oppose. We do not oppose water for the West. We would not oppose an Upper Colorado River Project which did not invade protected public lands in which we are interested.

"We are fighting the present Colorado River Project because we have no choice but to believe . . . that Echo Park 'is the piston in the engine' and is indivisible from the project as presently planned."

Here, then, is the stated crux of the controversy between the conservationists led by Smith and the

program of the Reclamation Service. This attitude is also supported by a telegram from the president of the Sierra Club of California to Utah's Senator A. V. Watkins, in which the president stated: "We ... wish to stress that the Sierra Club does not oppose a sound Upper Colorado Project that does not adversely affect National Parks, National Monuments or dedicated Wilderness Areas."

This vocal opposition was not willing to settle on the basis of official or legal agreements; it demanded a settlement based on its interpretation of the intrinsic values of the areas. It has not been made clear to the conservation conscious public that the building of the Echo Park project would not be an "invasion of protected public lands"; the dam would be constructed on lands exempted from Dinosaur National Monument for that purpose by Presidential proclamation, as shown in black on the map (Figs. 2 and 3). Insistence upon their demands would require the Reclamation Service to so revise its program as to annul its existing priorities under the Presidential proclamation although, of course, the conservationists could logically request reconsideration of the original Presidential reservations.

Southern California Opposition

The great developments in the Lower Colorado Basin by which about 4.5 million acre feet of water are supplied to southern California without Arizona's getting what it considers to be its share has led to litigation to settle the division of water among the lower basin states. The suit was originally instituted by Arizona against California and Nevada but was later enlarged to include Utah and New Mexico only to the extent of their interest in lower basin waters. The United States Supreme Court denied the effort of California to involve the upper basin states in the litigation.

The development and use of water by California without equivalent development in Arizona and in the upper basin is the main cause of the litigation. California is rapidly putting its share of water to beneficial use, but no one knows exactly how much is California's share. Other states fear that the application of water to such use by California will establish priority rights to the water that cannot be upset if California gets more than its proper share.

California's special water counsel stated before the Supreme Court that Arizona's claim was based on the assumption of a "community fund" of water, that the presence of all seven states is essential for a full settlement of the Colorado River water dispute, and that if Arizona's claim prevailed the California use of water would be curtailed from 4.5 million to 3.8 million acre feet. The insistence of California in attempting to maintain this preferred position has been the butt of many accusations from other states.

Upper basin spokesmen have accused California of "delaying tactics" in its efforts to draw the entire basin into the Arizona suit. A Utah spokesman is quoted in a newspaper article (*4*) as charging that the Supreme Court's decision "is evidence that California's position on the entire project is based not upon protecting its own rights but upon preventing the upper basin from developing its rights."

An editor of the *Salt Lake Tribune* (*5*) labeled the profit accruing to southern California from the failure of Arizona and the upper basin to utilize their share of the water as the "greatest water steal in western history." It was charged that since 1951, when the upper basin plans were matured, three California lobbying organizations had expended nearly $1 million in spreading "a multitude of lies and misrepresentation" about the project in order to defeat it in the Congress. It was explained that power produced by upper basin water running through power plants at Hoover Dam costs Californians approximately 1.3 mills per kilowatt hour for firm power and 0.62 mills for secondary power, much less than would have to be paid for substitute power if the upper basin water is lost by its use upstream. I am reliably informed that if the power from Hoover Dam had been sold for 6 mills, the price proposed to be charged for upper basin power, there would have been enough profit to pay for the building of the upper basin works without additional credit from the Federal Government. As it is, because power has been sold at "give-away rates," the benefits have accrued to the users of the lower basin power.

Echo Park Dam

The conservationist leaders seem to have focused attention on the proposed Echo Park Dam as a symbol of a threatened "invasion of the National Park System" without investigating the legal or historical background until it was uncovered by the very careful investigations of Senator A. V. Watkins (*2*). They thus found themselves in an untenable position that was difficult if not impossible to reverse. The original stand had probably been taken without a realization of the historic and legal background for the development of the conflict, but the misunderstanding has not up to date been made clear to the general public. Under this interpretation, such unrealistic statements as

"The wily and wasteful proposal of the Echo Park Dam" and the "Why Echo Park Dam must be stopped" helped to produce such political pressure in the House of Representatives that proponents of the Colorado program, failed to bring the bill to vote in 1955.

Typical of the propaganda used in these articles is this extract around which other arguments are built: "The National Park Service . . . admits flatly that the effect of Echo Park Dam on the monument would be 'deplorable.' But . . . it is a totally unnecessary *invasion of a national park area.* This would be the first such dam in a protected park area. . . . Parks and monument areas . . . have been kept out of bounds for the lumber interests, stockmen, and others—including Reclamation engineers—*who want to set a precedent.* . . ." Followers were exhorted "If you do not want to see national park areas *turned over to the vested interests for private development* . . . write to your senators and your congressmen today. . . ." (italics mine, indicating propaganda distortions and impugnment of motives).

Despite its distorted implications, the conservationist pressure seems to have been effective in forcing a revaluation of the Upper Colorado River Storage Program. The Echo Park Project was jettisoned from the program in the House of Representatives before the Congress recessed. The upper basin interests decided to revamp their program accordingly before Congress reconvened. Even the Secretary of the Interior announced that plans for the Colorado River program would be revised to eliminate the dams that conflicted with Dinosaur National Monument. The bill was passed by the House in that form.

Compromise Efforts

As early as 29 April 1955, Paul B. Sears called attention to the need for scientific analysis of controversial problems such as this (*6*). He stated, "It must become part of our habit of thought and a recognized procedure to insist that, in matters of public policy where verifiable physical knowledge is involved, such aspects of major problems be referred to impersonal, disinterested, and competent boards of scientists . . . . the air would be greatly cleared and an important principle established if the services of bodies representing all phases of science were called upon to analyze this and similar issues."

In a discussion of the Colorado River program (*7*), I suggested that the proposal before the Congress was ". . . being bogged down by diversionary tactics that miss the main point at issue: Shall the arid lands of the interior be made habitable . . . or shall they be doomed to remain arid with sparse populations? . . . Would it not be better for the Congress to authorize the development of the river basin, determine the policy of water use, provide funds for operation and refer minor items of dispute to some fact-finding scientific body for final adjudication, as Sears suggested?"

An attempt was made in the House of Representatives to provide a compromise by amending the bill H.R. 3383 of 15 June 1955 to provide for "the establishment of a board of eminent disinterested engineers not presently employed by the Federal Government" for the purpose, among other things, of studying alternatives to Echo Park units and reporting back to Congress by 31 December 1958. This did not satisfy the conservationists; they insisted on complete elimination of Echo Park. This proposed board of engineers, however, could not be considered as a satisfactory substitute for the boards of scientists representing all phases of science that were proposed by Sears.

Conclusions

It is obvious that the Colorado River development program was settled on the basis of political decision without reference to scientific boards of inquiry. It is encouraging, however, to report that one of the outstanding national park supporters expressed himself personally to me as willing to have such controversial issues studied scientifically.

It should be remembered that all conservation efforts are directed toward supplying human wants in balanced proportions and that the values of forests, parks, esthetic landscapes, and recreation sites must be weighed against the values of supplying water and power for homes, towns, cities, mines, industries, and farms. Trying to decide these values on the basis of political bias is about as sensible as using the ballot to determine whether 2 and 2 make 4.

It is well known that human muscular labor is exceedingly expensive. The commercial energy equivalent of a man's muscular energy for 1 week of work can be purchased for a few cents. Happily for us, the amount of physical energy used per person in the United States is equivalent to the work of 37 men—that is, each person on the average has the equivalent of 37 servants. This, of course, is one of the bases for our high standard of living. It frees people from labor for education, training, mental work, and recreation. Any source of waterpower that will produce electricity at a cost of less than 1 cent per killowatt hour is still an overwhelmingly good investment for relieving man of

labor. The prospects for harnessing atomic energy and sunshine give the future a still brighter outlook. With automobile transportation and more leisure, recreation sites will be in much greater demand.

Echo Park is a beautiful recreation site but so are other canyons and side canyons of the Colorado Basin that will not be marred by reservoir construction. A transcontinental road from Cortez, Colorado, across southern Utah through Blanding, the Natural Bridges National Monument, across the Colorado River and out of the rough country via Escalante to Bryce Canyon National Park would open scenic landscapes and recreation sites such as have never been dreamed about by the untutored public.

However, there is a serious danger that the overemphasis and the misinformation utilized by the conservation groups may do irreparable damage to the cause of conservation. The local people as a result of this action may become wary about establishing additional monuments in the Colorado Basin where they may hold the political whiphand in the matter.

An aspect of vital importance that has not been treated in this paper is the advantage to national defense that might result from this project. The interior region to be served by the Colorado storage program contains great stores of coal, oil, copper, iron ore, uranium, phosphate, salt, chemicals, and other useful minerals of value in developing industries vital to defense efforts. The program could help to spread industrial targets over wide areas and if necessary to go underground—the cliff faces in the rough country would give easy access to potential underground chambers hundreds or thousands of feet below the surface. If the interior arid areas were better developed, it would be a tremendous aid in caring for fleeing populations leaving the Pacific coast with threats of coastal bombing in time of war.

If the Sears approach were accepted and the controversial matters were referred to scientific boards for investigation, then a positive approach for getting the unbiased facts for Congressional consideration and decision would be the main problem for scientists. The Congress would still have to set the policies and make the decisions, but it would have data carefully prepared by people trained in the art of fact finding in all the various aspects of science that bear on the problem instead of the semantics of emotionally inspired propaganda.

When this problem of upper Colorado River storage is stripped of extraneous issues and diversionary tactics, the fundamental and basic problem emerges as the danger of establishing populations that depend on Colorado River water in excess of that provided by the compact because, as everyone knows, it would be difficult if not impossible to take water away from such people even if their claims are established by unconventional methods. The alternative seems to be for Arizona and the upper basin to compete with California in putting their shares of the water to beneficial use. This explains why the upper basin people should get their projects under way.

References and Notes

1. *U.S. News and World Report* (29 July 1955), pp. 30–32.
2. *Congressional Record* (28 Mar. 1955).
3. *Salt Lake Tribune* (14 July 1955), p. 16.
4. *Ibid.* (13 Dec. 1955).
5. *Ibid.* (2 Aug. 1955).
6. P. B. Sears, *Science* **121**, 5A (29 Apr. 1955).
7. A. M. Woodbury, *ibid.* **122**, 200 (1955).

On 28 Mar. 1956, the Senate and the House of Representatives passed by voice vote the $760-million Upper Colorado River irrigation and reclamation project. The bill (S 500), as sent to the President, authorized initial construction of a number of dams, power plants, and irrigation facilities. It required the Secretary of the Interior to protect Rainbow Bridge National Monument in developing Glen Canyon and declared that it was the "intention of Congress that no dam or reservoir constructed under the authorization of this act shall be within any national park or monument." The Echo Park Dam project was eliminated from the bill before passage.

Minds that are stupid and incapable of science are in the order of nature to be regarded as monsters and other extraordinary phenomena; minds of this sort are rare. Hence I conclude that there are great resources to be found in children, which are suffered to vanish with their years. It is evident, therefore, that it is not of nature, but of our own negligence, we ought to complain.—Marcus Fabius Quintilian.

BOOK REVIEWS

Niels Bohr and the Development of Physics. Essays dedicated to Niels Bohr on the occasion of his 70th birthday. W. Pauli, Ed., assisted by L. Rosenfeld and V. Weisskopf. McGraw-Hill, New York; Pergamon, London, 1955. vii + 195 pp. $4.50.

In the early part of this century, a small group of physicists and chemists (most of them under the age of 30) spearheaded a revolution in the ideas of physics which has had the profoundest effects on all of modern science and whose intellectual and philosophic implications are still in the process of being incorporated into our culture. This revolutionary development was the quantum theory; among its pioneers Niels Bohr, a giant among giants, has for 40 years stood in the forefront.

The contributions of Bohr to the development of modern physics cannot be measured in terms of his scientific works alone, significant as these were for the birth of quantum theory (for example, the Bohr atom, the correspondence principle). Above and beyond these, however, is the importance of Bohr as a teacher and as a philosopher. His institute, in Copenhagen, has been and continues to be the Mecca of theoretical physicists. There they have come, the young as well as Bohr's contemporaries, to learn, to discuss, and to clarify—a modern Athens presided over by a 20th-century Socrates.

It was in Copenhagen that Bohr's philosophy of quantum theory was developed. This, the principle of complementarity and its methods of application to the analysis of physical situations was first conceived as a means of defending the quantum theory against its classical opponents, as a technique for resolving the apparent contradictions that were (and still are, to some extent) relentlessly concocted by those to whom the quantum theory is philosophically abhorrent. But, in the hands of Bohr and his disciples, this philosophy has been developed into a powerful tool for further enlarging the theoretical horizons and for probing incisively into the significance and implications of the unfamiliar mathematical formalisms that have been required for the further development of the quantum theory. It is a philosophy that follows no school, or many schools, but bears the unmistakable imprint of Bohr's genius.

In honor of Bohr's 70th birthday, a number of his friends and collaborators have collected a volume of essays. Since the subject matter ranges over the entire field of modern physics, with only the (essentially unrestrictive) restriction that the subject is one to which Bohr has made some contribution, I can do no better than to list the essays and their authors: C. G. Darwin, "The discovery of atomic number"; W. Heisenberg, "The development of the interpretation of the quantum theory"; W. Pauli, "Exclusion principle, Lorentz group and reflexion of space-time and charge"; L. D. Landau, "On the quantum theory of fields"; L. Rosenfeld, "On quantum electrodynamics"; O. Klein, "Quantum theory and relativity"; H. B. G. Casimir, "On the theory of superconductivity"; F. L. Friedman and V. F. Weisskopf, "The compound nucleus"; J. A. Wheeler, "Nuclear fission and nuclear stability"; J. Lindhard, "On the passage through matter of swift charged particles."

These are not simplified digests for the nonspecialist. Nor are they exclusively survey articles, although some of them do have this aspect. Taken together, they provide an excellent panoramic view of the present-day status of theoretical physics. If the picture is somewhat discouraging—for we do appear to be facing rather formidable obstacles, which, in all likelihood, will require new and radical departures from the accepted directions—the outlook is, on the whole, optimistic. This optimism stems in no small measure from the conviction, inherent in all the essays, that the approach, which Bohr has been so instrumental in inculcating into modern physics, of confronting all new hypotheses with the common yardstick of unambiguous physically *observable* situations will, in the end, provide the key to the secrets of nature.

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The Caves Beyond. The story of the Floyd Collins' Crystal Cave exploration. Joe Lawrence, Jr., and Roger W. Brucker. Funk & Wagnalls, New York, 1955. xii + 283 pp. Illus. $4.75.

Floyd Collins' Crystal Cave is one of the larger caves of the Mammoth Caves area, northwest of Cave City, Kentucky. Most of them lie behind the Dripping Springs Escarpment, the front of a southeast-facing cuesta carved on the north- and west-dipping Cypress sandstone. Beneath this sandstone are the several limestones that at times have been collectively known as the Mammoth Cave limestone. In them are the caverns. Limestone regions are cave regions and the regions of sinking creeks and lost rivers, as these streams leave the surface for the subterranean by way of limestone sinks.

It is the Mammoth Cave National Park area, and Crystal Cave, along with others, is in the process of purchase for the park. It is one of the large ones with many miles of known underground passageways, only a part of which have been used commercially. Many are still unexplored.

The book is a narrative of the planning, execution, and experiences of the week-long underground exploring expedition of the National Speleological Society led by Joe Lawrence, Jr., in February 1954. Prominent in the organization were Jim Dyer, former manager of the cave, and Bill Austin, its present manager. Also included was William B. Miller, who, as a *Louisville Courier-Journal* reporter in 1925, had been active in the attempted rescue of Floyd Collins.

Exploration began as the party eased down through

the Scotchman's Trap, beyond which commercial visitors are not taken. A number one camp was set up perhaps a mile farther on. It was reached through a quarter-mile crawlway with the "keyhole," "straddle canyon," "bottomless pit," and "S curve" to make difficult ordinary progress, let alone the moving in of equipment and supplies. On a side passage was a second and more temporary camp.

From these camps, kept in operation by supply teams, little known and virgin passages were explored. There was the difficulty of penetrating these areas, the "endurance barrier," the "crawling," "canyon hopping," and "chimneying."

The cave is comparatively dry, and hence extensive dripstone formations are not developed. On the other hand, the relative dryness is more favorable to gypsum flowers and helictites. A featherlike gypsum flower was found covering a stalactite hanging from the ceiling. Such is a rarity, for there are considerable differences in conditions under which the two are formed.

The book is not particularly a scientific contribution, and little is added to fundamental knowledge of cave forming. There is even some scientific error. An attempt is made in a number of appendixes to cover geologic, biologic, and meteorologic aspects. Soil samples were collected for a study of the molds for possible pharmaceutical use.

It is a story of a large-scale underground exploration in which a better understanding of the extent and nature of this cave was attained. It is interesting reading, enhanced by many illustrations.

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The Microbes' Contribution to Biology. A. J. Kluyver and C. B. Van Niel. Harvard University Press, Cambridge, 1956. 182 pp. Illus. $4.

This brief book contains the Prather lectures presented by the authors at Harvard University in 1954. Their purpose was to outline some of the major contributions of microbiological research to the development of modern concepts in biology. The lectures were directed toward an audience of students in biology, and, as the authors note, were not meant for microbiologists. However, I feel sure that few microbiologists have such an extensive knowledge of their field that they would fail to find something of interest here.

The specialist may well be critical of details but he cannot fail to be impressed by the broad view and historical perspective of the authors. This book will be of inspirational value to students in all branches of biology who have had some training in biochemistry. To them this book is heartily recommended. The topics that are briefly surveyed include energy metabolism, photosynthesis, adaptation, mutation, and evolution as visualized by two eminent microbiologists.

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Biochemistry: an Introductory Textbook. Felix Haurowitz. Wiley, New York; Chapman & Hall, London, 1955. xvi + 485 pp. Illus. $6.75.

During the past two decades biochemists have made notable advances in the field of intermediary metabolism. It is therefore appropriate that new textbooks of biochemistry place considerable emphasis on the chemical transformations that occur in living matter.

The organization of Felix Haurowitz' book reflects this trend. Two chapters are allotted to discussion of enzymes and related matters. Briefly, the subjects presented are energetics and kinetics of enzymatically catalyzed reactions, energy coupling, types of reaction mechanisms, metabolic cycles, and a classification of enzymes. Both of these chapters are commendable efforts to reduce the complex jargon of the enzymologist to a language understandable by the beginning student of biochemistry.

Chapters on carbohydrates, proteins, lipids, nucleic acids, and porphyrins contain sufficient structural formulas and information on chemical properties to enable the student to follow intelligently the enzymatically catalyzed conversions that these compounds undergo. The degradation or synthesis of a particular compound is presented by discussion of stepwise reactions, where this is possible. The enzyme involved, the nature of the coenzyme, the need for an inorganic component, the energetics of the reaction, as well as the significance of the reaction-step, are emphasized. Along with each class of compounds, pertinent physiological phenomena are briefly presented.

Separate chapters are not devoted to the vitamins and hormones, nor are their physiological aspects discussed at length. Some of these biologically important substances are logically treated in discussions of chemical compounds whose metabolism they influence or whose structure they resemble; others are taken up in the chapter on nutrition.

An entire chapter is devoted to mineral metabolism. The important cations and anions are lucidly treated with reference to their metabolism, physiological effects, transport, and distribution.

The last chapter attempts to present the biochemistry of man. An adequate treatment of this subject in the space allotted would appear to be impossible.

The book is written in a very readable style and is remarkably free from errors.

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Eli Lilly and Company

Molecular Beams. K. F. Smith (ed. 2 of *Molecular Beams,* by Ronald Fraser, 1937). Methuen, London; Wiley, New York, 1955. x + 133 pp. Illus. $2.

The molecular-beam method was first introduced in 1911 and, after remaining dormant for almost a decade, developed rapidly into one of the most powerful tools

of modern physics. Its importance and success are attested by three Nobel prizes that have been awarded for its application. Nevertheless, it has attracted only a small number of experimenters and has remained relatively unknown to most physicists. This may be due, at least in part, to the lack of suitable monographs dealing with the subject; and the appearance of the book reviewed here is, therefore, a very welcome addition to the literature.

Formally, it is designated as the second edition of a small book by Ronald Fraser published in 1937, but actually about one-third of the volume deals with the resonance method introduced only since the appearance of the previous edition. Thus it is to a large extent a new book. The author's approach, particularly in the new part, includes discussion of results as well as theory, and although more details in the theoretical parts would have been helpful to many readers, the author has generally succeeded in finding a good compromise between clarity of expression and space limitations.

From a historical viewpoint, I miss a discussion of the significance of the basic experiments at the time of their conception and performance. The numerous references to original papers cannot be expected to be complete and in some cases do not include the first users of new methods or the final results of measurements. Aside from these minor criticisms, the book is very well written and for its size, comprehensive. It may be expected to acquaint many more physicists with the beauty and the power of the molecular-beam method.

I. ESTERMANN

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Science and Freedom, a Symposium. Proceedings of a conference convened by the Congress for Cultural Freedom and held in Hamburg 23–26 July 1953. The Congress. Beacon Press, Boston, 1955. 295 pp. $4.50.

This book, a conglomerate of papers and discussions varying widely in subject, will be read with interest and profit. It deals with problems of organization of science, relation of science and scientists to the state, scientific method, and conditions of scientific research in the U.S.S.R. The term *freedom* is not rigorously defined, and we find a discussion on freedom of scientific research alongside the discussion of whether science as such is free, or whether it is bound by its own rules and postulates. It might have been interesting to discuss the concept of freedom from an exact quantitative point of view. That this is possible, I have shown elsewhere.

It seems to me that the significance of the book lies not so much in what it contributes as in the fact that it is a symptom of our time. Science now influences directly or indirectly almost every step we take. Even half a century ago, some scientists could remain locked up in their ivory towers. Nowadays they can ill afford such an attitude.

As is indicated in the preface, there is considerable divergence of viewpoints. This divergence is surprisingly small, considering that the philosophic and sociopolitical views of scientists cover the whole range of the possible spectrum. Cauchy was a rabid royalist and a highly religious person; the Nobel prize-winning Lenard was a staunch Nazi and wrote anti-semitic pamphlets long before anyone heard of Hitler. On the other hand, such eminent scientists as J. B. S. Haldane and others of similar caliber belong to the long-weave end of the political spectrum.

That in spite of this no greater disparity of views is found may perhaps be due to some unavoidable selection. Scientists from communist countries were not present because of the political situation. The few Western scientists of the Lenard type are not likely to be interested in discussions of this kind. Let us hope that now, in line with the "Geneva spirit," a close intercourse between Eastern and Western scientists will become a reality, and that the next Congress on Cultural Freedom will be really international. Whether this will lead to a further divergence of opinions remains to be seen. Even if it does, it will be welcome as long as differences manifest themselves in friendly and calm academic discussions with complete tolerance for the views of the opponent. Truth is born from the clash of opinions.

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The Secret of the Hittites. The discovery of an ancient empire. C. W. Ceram. Translated from the German by Richard and Clara Winston. Knopf, New York, American ed. 1, 1956. $5.

C. W. Ceram, a German journalist and publisher, first became known to the American public as the author of the best seller *Gods, Graves, and Scholars.* His second archeological book, *The Secret of the Hittites,* focuses attention on the discoveries in Asia Minor and in particular on the recovery of the little-known Hittite civilization. Although the author is not a specialist, he has gathered his information carefully and, in weighing diverse opinions, has struck a balance that would be difficult for a specialist to attain, owing to his inevitable involvement in the issues.

The book is arranged in four sections, which describe (i) the limited literary sources and the results of early excavations, (ii) the identification of the language and the gradual decipherment of the scripts, (iii) the history of the Hittite Empire with special attention given to the Battle of Kadesh, and (iv) the excavations at Karatepe (since World War II) and the progress made in unraveling the Hittite hieroglyphs. It is well written throughout, and involved topics, such as the problems of ancient Near Eastern chronology, are lucidly presented. Ample photographs, line drawings (some of which are rough and schematic), maps, and a chronological table enable the reader to move easily through unfamiliar scenes, places, and times. The well-arranged and selective bibliography will be of benefit to students and specialists alike.

Although there is little argument with Ceram's fascinating presentation of the facts, several of his conclusions are questionable. One example will suffice. His assertion (pp. 214 f) that there was no Hittite culture is difficult to understand. From the point of view of archeology, and this is an archeological book, there most certainly was a Hittite culture. Its governmental organization, legal code, and religion were in part unlike those of surrounding cultures; its architecture, sculpture, pottery, and language were distinctive. Although there is evidence of organic development in certain aspects of the material culture, the extent of this development in the whole culture cannot be determined as yet.

The book is good reading and should enjoy a wide circulation.

GUS W. VAN BEEK
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The Unleashing of Evolutionary Thought. Oscar Riddle. Vantage, New York, 1955. xxi + 414 pp. $4.50.

I have been informed that one of the country's leading journals will not review *The Unleashing of Evolutionary Thought,* presumably because its author not only expresses his disbelief in a personal God but also indicts organized religion for obstructing the adequate teaching of biology. Neither book nor author being negligible, the attitude of this journal lends color to a thesis evidently not to its liking.

I have long believed that anyone who takes religion seriously enough to give it thought and express his honest doubts has more of it than those who swallow it whole and blindly, even though his inquiry may bring him to extremely unorthodox conclusions. The greatest spiritual leaders of mankind have not been noted for their complacent acceptance of prevailing attitudes. I am not arguing that Oscar Riddle is a great spiritual leader —he would be the first to disclaim such a role—but I do insist on his right to be heard.

What he has done is to assemble a mass of material quite familiar to scientists, supporting the idea that man, body and behavior, is an expression of the operation of natural law. He further suggests that many of the world's troubles would decrease if this were generally understood and accepted. That it has not been he considers largely due to the suppressive tactics of institutional religion. In support of this idea he quotes extensively from religious leaders. He goes to considerable trouble to show that man's moral qualities—compassion, cooperation, and the like—are not a sudden investiture upon an evolved and reluctant primate, but are characteristics that have their roots in an ancient biological past. With this few biologists would disagree.

Unless I do him an injustice, however, he does not sufficiently appreciate that the faiths of mankind stem in large part from the same fundamental desire that moves the scientist—that is, to establish some kind of meaning or consistency in the human adventure. This is the goal of every culture of which we have knowledge, and it is quite beside the point that the urge has been given form, or even at times exploited, by priestcraft during many stages of human history. If we substitute the word *pastor* for *priest* and recall the universal need of mankind for counsel and comfort that make sense in terms of the prevailing culture, our judgment of the record should not be too harsh. It might be even further mollified by reading two articles in *Science* [30 Dec. 1955] "Science and people," by Warren Weaver, and "Religion in an age of science," by Ralph W. Burhoe.

Riddle holds that the essential value of religion lies in its concern with ethical principles. It is his further view that ethical behavior does not require the support of religion, as commonly understood. His real quarrel, in the tradition of Haeckel and the Huxleys, is with theology and institutionalism. Unlike Thomas Huxley who, keenly aware of the provisional character of all knowledge, called himself an agnostic, he prefers to consider himself an atheist. Although this may be scientifically correct as a personal description, it certainly does not represent the attitude of suspended judgment which is in the best tradition of science.

I have good reason to know how much trouble has its origin, even in our enlightened country, in widespread scientific illiteracy. But the difficulty there lies, in my judgment, at a much more elementary level than the acceptance or rejection of organic evolution. At this stage in human history the common man suffers more from his bland disregard of simple arithmetic, simple physics, and simple natural history than from his ignorance of Einstein's terrifying equation or the biogenetic law.

More than this, he has the same right (and a profound need) to express his conception of the universe in poetic imagery, ritual, music, and fellowship that the scientist claims for his system of symbols and their communication. At a higher level, a philosopher's insistence on an ultimate cause is as legitimate as the scientist's faith (for it is faith) in a consistent natural universe. Neither has a right to place limits upon the other's quest. Both have the right to question. But, more fundamentally, all—philosopher, scientist, and common man—are parts of humanity, with common problems and the need for some common understanding. Except for temporary emphasis, this is not promoted by anyone's conviction that he holds the only keys to truth. There is an ancient saying, "Study in the field of your prejudices," and another "Beware the man of one book."

I applaud both Riddle's concern to have mankind understand itself and its universe and his deep and sincere moral purpose. But I wonder whether he has looked far enough behind the fact that every human culture has had its faith and has expressed that faith as drama. The fault of the religious fundamentalist may be not so much his ignorance of science as his failure to comprehend the nature of poetry. The scientist ought not fall into the same trap.

PAUL B. SEARS
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Observational Astronomy for Amateurs. J. B. Sidgwick. Faber and Faber, London, 1955 (distributed by Macmillan, New York). 358 pp. Illus. $10.

This book is heartily recommended for the library of the serious amateur—who desires to select a field for concentration of his observations and work carefully at it. Section by section, concise reliable outlines are given of methods, types of data, and formulas. There are in all 20 sections, with the following titles: "Solar observation"; "Lunar observation"; "General notes on planetary observation"; "Mercury"; "Venus"; "Mars"; "Jupiter"; "Saturn"; "Uranus"; "Neptune"; "Pluto" (two pages); "Asteroids"; "Zodiacal light, Gegenschein, and zodiacal band; "Aurorae"; "Meteors"; "Comets"; "Variables"; "Binaries"; "Nebulae and clusters" (one page only); and "Bibliography." The last occupies pages 311–319 and includes separate listings by chapters.

There is a brief index. An appendix presents a full table of contents of the same author's earlier companion volume, *Amateur Astronomer's Handbook*. Each volume is self-contained and independent.

No one not already well informed about astronomy would get much out of this book. No reader, however well informed, can look through it without coming across interesting items new to him. J. B. Sidgwick, himself a fellow of the Royal Astronomical Society, acknowledges aid from ten section directors of the British Astronomical Association with respect to parts related to their special knowledge.

Naturally, there is not space for all that might have been included. Any conscientious reader who buys the book ought to paste in a flyleaf suggestions of additional points made by an earlier reviewer, M. B. B. Heath [*J. British Astronomical Assoc.* **66**, 37 (1955)]. Doubtless many others might be added. For instance, amateurs who may have the good fortune to observe a total solar eclipse could arrange a more useful program than page 57 includes [see *Popular Astronomy* **53**, 477 (1945) and **54**, 20 (1946)]. And, in this country, although we have no general society of amateur astronomers, several separate groups, such as variable-star observers, meteor observers, and students of sunspots, furnish their members with more special guidance than can be sought in a general publication. The book is excellently printed and attractively bound.

JOHN Q. STEWART

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The Expression of the Emotions in Man and Animals. Charles Darwin. With a preface by Margaret Mead. Philosophical Library, New York, authorized ed., 1955. xi + 372 pp. Illus. + plates. $6.

In this reissue of Darwin's book we miss only the more modern projective test methods and cybernetics. On the other hand, Darwin with his excellent observations on all living procedures brought out the following important facts. The movements of expression serve as a first means of "communication" between mother and infant. The mother smiles approval or frowns disapproval. Expression gives vividness and emphasis to the spoken word. Like Gratiolet, Darwin believed that possible repression softens our emotions and that violent gestures increase rage. Uncontrolled fear produces more fear. Remaining passive when one is overwhelmed by sorrow or anxiety reduces the best chance of regaining the elasticity of the mind. This is because of the intimate relationship between emotions and outward manifestations as well as because of the exertion on the heart and brain.

Darwin conluded with the affirmation that the theory of expression supports the concept that man is derived from some lower animal and the belief of the specific or subspecific unity of all races. Furthermore, the language of the emotions is certainly of importance for the welfare of mankind.

ALBERT REISSNER

Alfred Adler Mental Hygiene Clinic

Wild America. The record of a 30,000-mile journey around the continent by a distinguished naturalist and his British colleague. Roger Tory Peterson and James Fisher. Houghton Mifflin, Boston, 1955. xii + 434 pp. Illus. $5.

Here is a book that stands out in its field like a giant among pygmies. Not only is it well written, but it is filled to the brim with illustrations which alone are worth its price.

England's James Fisher has become increasingly well known to Americans as a biologist who can write about birds with infectious enthusiasm and as an editor of the "New Naturalist" series. He had never set foot in North America until 11 Apr. 1953, but in the next 100 days he traveled 30,000 miles, seeing more of America than do the vast majority of American naturalists in a lifetime. His guide was Roger Tory Peterson, America's best-known field ornithologist, whose passion for birds matches Fisher's. We expected a good book to result from such a trip by such a pair. *Wild America* is much more than that—it is a classic that will delight all naturalists, young or old, and reassure many a weary conservationist.

Their book is intriguing, because Peterson and Fisher, off to see as many species of birds as possible, had eyes for so many other things—other animals, plants, rocks, landscapes, seascapes, and all the awe-inspiring beauty that is America's heritage. From Newfoundland around the perimeter of the continent, with a dip into Mexico and a final flight to Alaska and the Pribilof Islands, chapter after chapter is filled with their adventures, impressions, and an abundance of sound ornithology. Rare, indeed, will be the bird student who does not learn some new facts about bird distribution from this book.

Many readers will appreciate the concluding chapters most of all. Too few Americans appreciate what fabulous populations of animals exist in Alaska and the chain of islands stretching westward through fog-shrouded waters. There is an excellent account of bird distribution in this little-known corner of the earth, and wildlife managers will find interesting the careful delineation of fur-seal harvesting techniques. An appendix on the history of the fur-seal herds is a useful contribution.

A special word must be said about the abundant illustrations. Those who have watched Roger Peterson's steady progress as a bird artist over the past two decades will find that he has suddenly taken a great giant's-step forward. The full-page drawings reveal a new Peterson style that is almost breath-taking.

As an appraisal of wild America at mid-century and as an entertaining and instructive thing of beauty, this book is unreservedly recommended.

ALFRED E. EYNON
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Books Reviewed in SCIENCE

6 April

The Fossil Evidence for Human Evolution, W. E. Le Gros Clark (Univ. of Chicago Press). Reviewed by F. C. Howell.

Biochemistry of the Developing Nervous System, H. Waelsch, Ed. (Academic). Reviewed by D. Nachmansohn.

Small-Angle Scattering of X-rays, A. Guinier and G. Fournet (Wiley; Chapman & Hall). Reviewed by I. Fankuchen.

Echinodermata, vol. IV of *The Invertebrates,* L. H. Hyman (McGraw-Hill). Reviewed by E. Deichmann.

The Atomic Nucleus, R. D. Evans (McGraw-Hill). Reviewed by G. M. Volkoff.

Traité de Paléontologie, vol. V (Masson). Reviewed by E. H. Colbert.

13 April

The Biochemistry of Semen, T. Mann (Methuen; Wiley). Reviewed by J. T. Velardo.

Topley and Wilson's Principles of Bacteriology and Immunity, 2 vols., G. S. Wilson and A. A. Miles (Williams & Wilkins). Reviewed by J. R. Porter.

Functional Analysis, F. Fiesz and B. Sz.-Nagy (Ungar). Reviewed by N. Levinson.

Gas Kinetics, A. F. Trotman-Dickenson (Academic; Butterworths). Reviewed by H. S. Johnston.

Active Transport and Secretion, No. VIII, R. Brown and J. F. Danielli, Eds. (Academic). Reviewed by R. S. Anderson.

Proceedings of the 1954 Glasgow Conference on Nuclear and Meson Physics, E. H. Bellamy and R. G. Moorhouse, Eds. (Pergamon).

20 April

The Extra Pharmacopoeia, vol. 2 (Pharmaceutical Press, ed. 23). Reviewed by G. L. Jenkins.

Industrial and Manufacturing Chemistry, vols. I and II, G. Martin (Philosophical Library). Reviewed by W. J. Murphy.

The ISCC-NBS Method of Designating Colors and a Dictionary of Color Names, NBS Circular 553 (National Bureau of Standards). Reviewed by D. Nickerson.

Actions chimiques et biologiques des radiations, M. Haissinsky, Ed. (Masson). Reviewed by G. E. Stapleton.

Radiocarbon Dating, W. F. Libby (Univ. of Chicago Press). Reviewed by W. L. Straus, Jr.

27 April

The Development of Academic Freedom in the United States, R. Hofstadter and W. Metzger (Columbia Univ. Press). Reviewed by B. Glass.

Academic Freedom in Our Time, R. M. MacIver (Columbia Univ. Press). Reviewed by B. Glass.

Soviet Professional Manpower, Its Education, Training, and Supply, N. DeWitt (National Science Foundation). Reviewed by H. H. Armsby.

The Soviet Academy of Sciences, A. Vucinich (Stanford Univ. Press). Reviewed by C. Zirkle.

Immunology and Serology, P. L. Carpenter (Saunders). Reviewed by W. C. Boyd.

Methods in Enzymology, vols. I and II, S. P. Colowick and N. O. Kaplan (Academic). Reviewed by R. S. Schweet.

Advances in Virus Research, vol. III, K. M. Smith and M. A. Lauffer, Eds. (Academic). Reviewed by M. H. Adams.

A Symposium on Inorganic Nitrogen Metabolism: Function of Metallo-Flavoproteins, W. D. McElroy and B. Glass, Eds. (Johns Hopkins Univ. Press). Reviewed by S. B. Hendricks.

The Blood-Brain Barrier with Special Regard to the Use of Radioactive Isotopes, L. Bakay (Thomas). Reviewed by J. R. Pappenheimer.

Physical Techniques in Biological Research, vol. I, G. Oster and A. W. Pollister, Eds. (Academic). Reviewed by H. Yagoda.

Embryologie, D. Starck (Thieme). Reviewed by P. Weiss.

Annual Review of Entomology, vol. I, E. A. Steinhaus and R. F. Smith, Eds. (Annual Reviews). Reviewed by J. S. Wade.

Traité de zoologie, vol. XVII (Masson). Reviewed by D. H. Johnson.

Evolution, Genetics, and Man, T. Dobzhansky (Wiley; Chapman and Hall). Reviewed by W. S. Stone.

The Recent Genera of the Caridean and Stenopodidean Shrimps (Class Crustacea, Order Decapoda, Supersection Natantia) with Keys for Their Determination, L. B. Holthuis (Brill). Reviewed by W. L. Schmitt.

Medical Research: a Midcentury Survey, vol. I, American Foundation. Reviewed by W. Cutting.

Research Frontiers in Politics and Government, S. K. Bailey, H. A. Simon, R. A. Dahl, R. C. Snyder, A. de Grazia, M. Moos, P. T. David, D. B. Truman (Brookings Institution). Reviewed by A. E. Burns.

The Mighty Force of Research, Editors of *Fortune* (McGraw-Hill). Reviewed by G. DuShane.

What Is Science? J. R. Newman, Ed. (Simon and Schuster). Reviewed by A. Sayvetz.

Atomic Power; Automatic Control; First Book of Animals; The New Astronomy; The Physics and Chemistry of Life, Editors of *Scientific American* (Simon and Schuster). Reviewed by J. Turner.

The Biology of the Spirit, E. W. Sinnott (Viking). Reviewed by C. A. Coulson.

Language, Thought, and Reality, J. B. Carroll, Ed. (Technology). Reviewed by S. Saporta.

Scientific Books, Libraries, and Collectors, J. L. Thornton and R. I. J. Tully (Library Association). Reviewed by M. C. Leikind.

Science and Christian Belief, C. A. Coulson (University of North Carolina Press). Reviewed by E. W. Sinnott.

Ludwig Boltzmann, Mensch, Physiker, Philosoph, E. Broda (Deuticke). Reviewed by K. Lark-Horovitz.

Relativity: the Special Theory, J. L. Synge (North Holland; Interscience). Reviewed by P. G. Bergmann.

Imagination's Other Place, H. Plotz, Comp. (Crowell). Reviewed by J. M. Forbes.

Biographical Memoirs of Fellows of the Royal Society, vol. I (Royal Society). Reviewed by G. DuShane.

Poliomyelitis, International Poliomyelitis Congress (Lippincott).

Ergebuisse der Medizinischen Grundlagenforschung, K. F. Bauer (Thieme).

Bone, an Introduction to the Physiology of Skeletal Tissue, F. C. McLean and M. R. Urist (Univ. of Chicago Press).

Arctic Research, D. Rowley, Ed. (Arctic Institute of North America).

Preventive Medicine in World War II, vol. III, E. C. Hoff, Ed. (Office of the Surgeon General, Dept. of the Army).

Shock and Circulatory Homeostasis, H. D. Green, Ed. (Josiah Macy, Jr. Foundation).

Electronic Transformers and Circuits, R. Lee (Wiley; Chapman and Hall). Reviewed by R. F. Shea.

Principles and Problems in Energetics, J. N. Brønsted (Interscience). Reviewed by G. M. Murphy.

Mesons and Fields, vol. I, S. S. Schweber, H. A. Bethe, F. de Hoffman (Row, Peterson). Reviewed by D. C. Peaslee.

An Introduction to Reactor Physics, D. J. Littler and J. F. Raffle (McGraw-Hill; Pergamon). Reviewed by M. M. Shapiro.

Principles of Guided Missile Design, A. S. Locke, C. H. Dodge, S. F. George, L. F. Gilchrist, W. C. Hodgson, J. E. Meade, J. A. Sanderson, C. F. White (Van Nostrand). Reviewed by R. L. Garman.

Astrophysical Quantities, C. W. Allen (Athlone). Reviewed by L. H. Aller.

Principles of Physical Metallurgy, M. C. Smith (Harper). Reviewed by J. C. Wilson.

Structural Geology for Petroleum Geologists, W. L. Russell (McGraw-Hill). Reviewed by P. B. King.

New Zealand Geomorphology, C. A. Cotton (New Zealand Univ. Press). Reviewed by E. W. Berry.

Physical Chemistry, F. Daniels and R. A. Alberty (Wiley; Chapman and Hall). Reviewed by M. E. Hobbs.

Chemical Engineering, vol. 2, J. M. Coulson and J. F. Richardson (McGraw-Hill; Pergamon). Reviewed by J. M. Dalla-Valle.

Biochemistry and the Central Nervous System, H. McIlwain (Little, Brown). Reviewed by G. M. Tomkins.

Androgens, R. I. Dorfman and R. A. Shipley (Wiley; Chapman and Hall). Reviewed by J. T. Velardo.

A Solomon Island Society, D. L. Oliver (Harvard Univ. Press). Reviewed by M. H. Fried.

Information Theory in Psychology, H. Quastler, Ed. (Free Press). Reviewed by F. C. Frick.

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The Mathematics of Physics and Chemistry. Henry Margenau and George M. Murphy. Van Nostrand, Princeton, N.J., ed. 2, 1956. 604 pp. $6.85.

Progress in Biophysics and Biophysical Chemistry. vol. 6. J. A. V. Butler, Ed. Pergamon, London, 1956. 274 pp. $9.50.

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Laboratory Manual of Vertebrate Embryology. Robert Rugh. Burgess, Minneapolis, rev. ed., 1956. 250 pp. $3.

A Laboratory Guide for Elementary Physiology. Oscar E. Tauber, Delma E. Harding, and Robert E. Haupt. Burgess, Minneapolis, 1955. 224 pp. $3.

Nellie Landblom's Copybook for Beginners in Research Work. Nellie Thompson Landblom. The author, P.O. Box 248, Fort Collins, Colo., 1955. 118 pp. Paper, $2.95.

Numerical Analysis. With emphasis on the application of numerical techniques to problems of infinitesimal calculus in single variable. Zdenek Kopal. Wiley, New York, 1955. 556 pp. $12.

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Comparative Endocrinology of Vertebrates. pt. II, ***The Hormonal Control of Water and Salt-Electrolyte Metabolism in Vertebrates.*** Proceedings of a conference held at the Department of Zoology, University of Liverpool, 12–16 July 1954. Memoirs of the Society for Endocrinology No. 5. I. Chester Jones and P. Eckstein, Eds. Cambridge University Press, New York, 1956. 124 pp. $4.75.

Topological Dynamics. American Mathematical Society Colloquium Publ., vol. XXXVI. Walter Helbig Gottschalk and Gustav Arnold Hedlund. American Mathematical Society, Providence, R.I., 1955. 151 pp. $5.10.

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The Analytical Theory of Heat. Joseph Fourier. Alexander Freeman, trans. Dover, New York 19 (unabridged republication of the English translation first published 1878), 1955. 466 pp. $1.95, paper.

The Number-System. H. A. Thurston. Interscience, New York, 1956. 134 pp. $2.50.

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Essays on Science. Herman Augustus Spoehr. Foreword by C. Stacy French; contributions by Alexander Spoehr, Hortense Spoehr Miller, James H. C. Smith; bibliography compiled by Wilbur A. Pestell. Stanford University Press, Stanford, Calif., 1956. 220 pp. $5.

Essays in Educology. Being the first report from the archives of the Association for the Preservation of Humor in Educological Workers. Lowry W. Harding. Brown, Dubuque, Iowa, 1956. 186 pp. $2.50.

Life, the Great Adventure. Jean Rostand and Paul Bodin (based on a translation by Alan H. Brodrick). Scribner's, New York, 1955, 1956. 228 pp. $3.50.

Surveys in Mechanics. A collection of surveys of the present position of research in some branches of mechanics, written in commemoration of the 70th birthday of Geoffrey Ingram Taylor. G. K. Batchelor and R. M. Davies, Eds. Cambridge University Press, New York, 1956. 475 pp. $9.50.

Sunken Islands of the Mid-Pacific Mountains. Memoir 64. Edwin L. Hamilton. Geological Society of America, New York, 1956. 97 pp.

Die Septische Thrombophlebitis. Ihre Entstehung und Aysbreitung auf dem Blutwege. Was leistet die Venenunterbindung? Fritz Felsenriech und A. Kristinsky. Maudrich, Vienna-Bonn, 1955, 94 pp. $2.88.

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New Worlds of Modern Science (reprints from various sources). Leonard Engel, Ed. Dell, New York, 1956. 383 pp. $0.35.

Gestation. Transactions of the second conference 8–10 March 1955, Princeton, N.J. Claude A. Ville, Ed. Josiah Macy, Jr. Foundation, New York, 1956. 262 pp. $5.

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